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VOLUME 29 | SEPTEMBER, 1955 | NUMBER 5

SOME ORDOVICIAN BRACHIOPODS FROM MINNESOTA AND THEIR STRATIGRAPHIC RELATIONS[1]

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ABSTRACT—Two new Middle Ordovician rock units are described: the Carimona interbedded limestone and shale member at the top of the Platteville formation, and the Cummingsville interbedded shaly limestone and limestone member constituting the lower one-third of the Galena formation. A new subspecies of *Plectorthis plicatella* is described, and thirteen species of nine brachiopod genera are discussed and illustrated.

INTRODUCTION

A RECENT study (Weiss, 1953) of Middle Odovician rocks in southeastern Minnesota necessitated certain stratigraphic and paleontologic changes. This paper formally defines two new rock units (members), revises some species of four brachiopod genera, and includes new illustrations and stratigraphic data for some species of five other brachiopod genera. W. C. Bell, R. L. Bates, and A. LaRocque kindly made many suggestions toward the improvement of this paper.

PLATTEVILLE FORMATION

The Platteville formation comprises limestones and dolomitic limestones that overlie sandy shales (Glenwood) at the top of the St. Peter formation and underlie green calcareous shales of the Decorah formation. In southeastern Minnesota the Platteville consists of three members: Pecatonica, McGregor, and Carimona, in stratigraphic order. The Pecatonica member is a medium-bedded sandy dolomitic or magnesian limestone that thins rapidly to a feather edge in central Filmore County. The McGregor is a thin- and crinkly-bedded microgranular limestone. The Carimona member (new) consists of thin and medium beds of very fine-grained limestone separated by thin and medium beds of yellowish-brown or olive shales.

Carimona Member

Carimona is the name proposed for the few feet of limestone and interbedded limestone and shale at the top of the Platteville formation and underlying the green shales of the Decorah formation. The name is derived from the hamlet of Carimona, 4.5 miles west of Preston, Fillmore County, Minnesota, and in the S½ Sec. 4, T. 102 N., R. 11 W. The member is typically developed in central Fillmore County. Three measured sections are given below.

The limestone beds of the member are pale yellowish-brown, very fine and fine-grained, and medium-bedded, and have smooth to broadly rippled surfaces. The

[1] Published with the permission of the Director, Minnesota Geological Survey; cost of plates borne in part by Minnesota Geological Survey.

limestones are separated by beds of shale that increase in thickness from bottom to top of the unit. The shales are yellowish-brown to olive, calcareous, fissile, and poorly fossiliferous. Near the base of the member a thin unfossiliferous chocolate-colored shale is overlain by a conspicuous bed of bentonite 2 to 4 inches in thickness. Locally there are thin patches of shale over the bentonite.

Carimona limestone beds characteristically fracture normal to the plane of bedding, and the broken edges are hackly. This is in marked contrast to the smooth, conchoidal fracture of the underlying McGregor beds. The two uppermost beds of limestone are somewhat less brownish and more gray than the rock below, are mottled with patches of medium gray, and are pyritic.

The Carimona member is moderately fossiliferous. Its uppermost beds contain specimens of *Pionodema* and *Sowerbyella*, the lowest stratigraphic position at which these two genera were found in association. Brachiopods are most numerous, but large endoceroid cephalopods are most spectacular. The thick limestone bed overlying the bentonite is divided symmetrically into three units by two zones of concentration of argillaceous fucoids, gastropod molds, and occasional cephalopod molds, all with abundant coarse recrystallized calcite in the interstices. These two zones weather out rapidly, leaving the three limestone beds separated by shaly intervals.

The Carcimona member is quite distinct from the McGregor in grain size, color, fracture, bedding, and shale distribution, although the uppermost McGregor shows some of the quality of Carimona bedding and grain size. The contact is placed below a thin yellowish-brown or chocolate-colored calcareous unfossiliferous fucoidal shale. Toward the southeast this thin shale is separated from the bentonite by less than an inch of limestone, but in the type area and toward the northwest two medium beds of limestone, separated by a thin shale, intervene between the fucoidal shale and the bentonite. The Carimona member extends upward to include the highest bed of Carimona-type limestone, and consequently includes a few thin beds of greenish, Decorah-type shale. Although the Platteville and Decorah formations are clearly transitional and conformable, the arbitrary contact between them is evident at almost every exposure.

The Carimona limestones typically contain 5 to 10 percent of insolubles, generally clay, less commonly silt. Pyrite occurs in most residues, but is more common in the upper part. Conversely, phosphatic materials (mostly conodonts, with some fragments of supposed scaphopods) are more abundant in the lower part. The limestones are calcarenites with abundant fossil fragments. The pyrite occurs in a few vugs, but mostly on the surfaces of fossils and fossil fragments.

The even beds of the Carimona member have been quarried extensively for rural building stone, and numerous exposures can be found throughout southeastern Minnesota. Across Fillmore County the member thickens regularly northwestward from 3 to 6 feet, and extends without much increase in thickness to the Twin Cities. It thins to a few inches in southwestern Wisconsin, where it underlies the Spechts Ferry member of the Decorah formation. The Carimona occupies the same stratigraphic interval as the Quimbys Mill member, but the members are lithologically distinct and are not known to overlap.

Section South of Fountain (F95)

Section in road cut and gulch on Highway 52, 1.5 miles south of Fountain, Minnesota (Sec. 14, T. 103 N., R. 11 W.). The base of the section is the top of the sandstone and sandy shale of the Glenwood formation. Only the Carimona member is here described in detail.

Decorah formation: green fissile calcareous shale.
Platteville formation: 20 feet 6 inches

	Feet	Inches
Carimona member: 4 feet 11 inches		
24. Limestone; medium light gray, very fine-grained and microgranular, mottled, fragmental, poorly fossiliferous, in two beds separated by shale, the lower smooth and the upper very rough on top.		7
23. Shale; pale brown, fissile, calcareous, unfossiliferous.		2

22. Limestone; medium light gray and brownish gray, very fine-grained, mottled, separated into two smooth beds by shale parting, poorly fossiliferous. With *Pionodema subaequata*. 7
21. Shale; green to olive, fissile, calcareous, unfossiliferous, with thinly-laminated highly calcareous light olive gray brittle petroliferous shale at the base. A limestone bed, dark gray and medium-grained above and greenish-gray microgranular below, occurs locally at the top. With *Pionodema subaequata, Strophomena incurvata, Eomonorachus intermedius*, and *Isotelus* sp. in the limestone lenses and the hard shale. 5
20. Limestone; light olive gray, microgranular to very fine-grained, pyritic, fragmental, with cephalopods in the top. With *Pionodema* sp. and *Strophomena* sp. 5
19. Limestone; pale yellowish-brown, very fine-grained, roughly bedded, argillaceous, crinoidal, fragmental, with numerous gastropod molds. With *Lingula* sp., *Pionodema subaequata, Strophomena* sp., and *Actinoceras* sp. 5
18. Limestone; pale yellowish-brown, very fine-grained, even bed, pyritic, with cephalopod and gastropod molds concentrated in the upper part. With *Pionodema subaequata, Protozyga nicolleti, Strophomena incurvata, isotelus* sp., and fucoids. 5
17. Limestone; pale yellowish-brown above, grayish-yellow next the bentonite very fine- to fine-grained, fairly even bed with big cephalopod molds in the top. 8–10
16. Bentonite; yellowish orange, with thin, laminated, calcareous, unfossiliferous shale below. 4
15. Limestone; dark olive to brownish-gray, fine-grained fairly smooth bed with broad ripples on top, fragmental, pyritic, unfossiliferous. 4–5
14. Shale; brown, thinly laminated, calcareous, unfossiliferous. 2
13. Limestone; light brownish gray, very fine-grained, smooth bed, fragmental, pyritic, unfossiliferous, with thin chocolate colored shale at the base. 4

McGregor member: 15 feet 7 inches, light olive gray microgranular crinkly-bedded limestone.

Section North of Fountain (F96)

Road cut on Highway 52, 3.0 to 3.5 miles north of the railroad overpass in Fountain, Minnesota (NE¼ Sec. 27, T. 104 N., R. 11 W.). Base of the section is the top of the cross-bedded sandstone of the Glenwood formation. Only the Carimona member is here described in detail.

Decorah formation: green, fissile, calcareous shale.
Platteville formation: 20 feet, 9 inches
Carimona member: 5 feet, 2 inches

	Feet	Inches
22. Limestone; pale yellowish-brown, microgranular and very fine-grained, in 2–3 beds separated by thin shale partings, argillaceous, fragmental, mottled. With *Pionodema subaequata, Sowerbyella punctostriata*, and conodonts.	1	2
21. Shale; green, fissile, calcareous, unfossiliferous, weathering yellowish.		5
20. Limestone; medium olive gray, microgranular to very fine-grained, very fossiliferous; the "*nicolleti*" bed. With *Pionodema subaequata, Protozyga nicolleti, Strophomena incurvata, Eomonorachus* sp., *Hormotoma gracilis*, and conodonts.		2
19. Shale; yellowish-brown, thinly laminated, calcareous, unfossiliferous		2
18. Limestone; olive gray, very fine-grained, smooth bed, fragmental, very poorly fossiliferous.		4
17. Limestone; pale yellowish-brown, microgranular and very fine-grained, rather crinkly-bedded, weathering light gray, with numerous gastropod molds, set off by rippled shaly partings. With *Doleroides pervata, Pionodema subaequata, Protoyza nicolleti, Strophomena incurvata, Loxoplocus* sp., and conodonts.		5–6
16. Limestone; pale yellowish-brown, very fine-grained, in 2–3 beds parted by shales, poorly fossiliferous. With *Pionodema subaequata*.		7–8
15. Limestone; pale yellowish-brown, very fine-grained, coquinoid, in two even beds with shale partings. With *Doleroides perveta, Pionodema subaequata, Bucania* sp., *Hormotoma gracilis*, and conodonts.		6–7
14. Bentonite; yellowish-orange, unfossiliferous, with light brown thinly laminated calcareous shale at the base.		3

13. Limestone; olive gray, microgranular with coarser parts up to coarse-grained, pyritic, fragmental, crinoidal, with top inch more brownish. With *Doleroides perveta*, *Pionodema subaequata*. 5
12. Shale; yellowish-brown, fissile, calcareous, unfossiliferous. 2
11. Limestone; pale yellowish-brown, microgranular and very fine-grained, even bed, fragmental, very poorly fossiliferous, underlain by thin chocolate-colored fucoidal shale. With *Lingula* sp. 5

McGregor member: 15 feet, 7 inches, light olive to yellowish gray, microgranular crinkly-bedded limestone.

Highway 16 Section (F144)

Roat cut on Highway 16, 1.3 miles west of the junction with Highway 52 north of Preston, Minnesota (center of N½ Sec. 35, T. 103 N., R. 11 W.). Base of the section is the top of the sandstone of the Glenwood formation. Only the Carimona member is here described in detail

Decorah formation: green fissile calcareous shale.

Platteville formation: 20 feet, 11 inches

Carimona member: 5 feet, 6 inches

	Feet	Inches
22. Limestone; mottled light olive gray and light brownish-gray, microgranular to very fine-grained, smooth bed with rippled base, fragmental. With *Protozyga nicolleti*, *Skenidioides anthonense*, *Sowerbyella punctostriata*, *Schmidtella* sp. and conodonts.		10
21. Shale; dusky yellow, weathered, fissile, calcareous, unfossiliferous.		3
20. Limestone; pale greenish-yellow, microgranular to very fine-grained, from 1 to 4 beds depending upon the state of weathering, with shaly partings, poorly fossiliferous. With *Pionodema subaequata*, *Skenidioides anthonense*, *Cyrtodonta* sp., and *Schmidtella* sp.		8
19. Shale; green, weathering yellowish, calcareous, with thin limy streaks, unfossiliferous.		4
18. Shale; grayish-yellow, very thinly laminated, very calcareous, unfossiliferous; at most localities not distinct from the shale above.		2
17. Limestone; yellowish-gray, microgranular and very fine-grained, even beds with shaly streaks, very pyritic, zone of fucoids and gastropod molds at base and 8 inches from the top. With *Pionodema subaequata*, *Protozyga nicolleti*, *Schmidtella* sp., and conodonts.	1	6

EXPLANATION OF PLATE 69

FIGS. *1a, b—Plectorthis plicatella* (Hall). *1a*, ventral exterior of silicified specimen, ×1, T6707; *1b*, dorsal exterior of the same specimen, ×1. Prosser member, Galena formation, Root River Quarry (F141.8W). (p. 767)

2–4—Plectorthis plicatella trentonensis Foerste. *2*, ventral interior of silicified specimen, ×3, T6703a, Pederson's Quarry (F87.37W); *3*, dorsal interior of silicified specimen, ×3, T6703b, Pederson's Quarry (F87.37W); *4a–c*, ventral, dorsal, and lateral views of silicified specimen, ×1, T6705, Root River Quarry (F141.3W). All from Prosser member, Galena formation. (p. 767)

5, 6—Plectorthis plicatella minnesotensis, Weiss, n. subsp. *5*, dorsal exterior of calcareous specimen, ×2, T6706, upper McGregor member, Platteville formation, Sugar Creek Annex (F146W); *6*, ventral exterior of calcareous specimen, ×1, T6704, basal Decorah formation, Gatzke Farm (F88.8W). (p. 768)

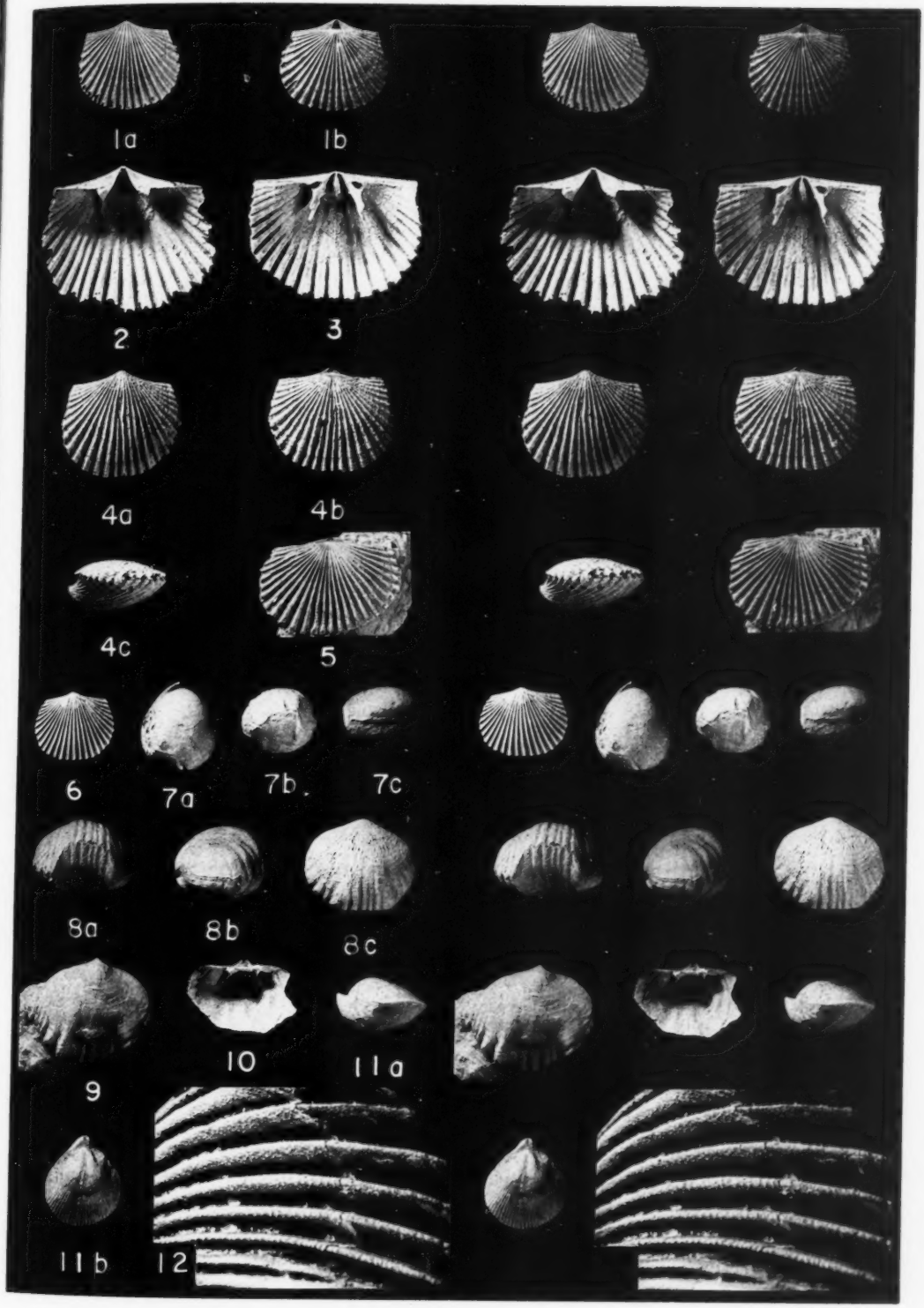
7a–c—Camerella panderi Billings. Dorsal, anterior, and lateral views of calcareous specimen, ×1.5, T6712a, lower part of Decorah formation, Spring Grove underpass (F85.44B). (p. 769)

8, 9—Parastrophina hemiplicata (Hall). *8a–c*, anterior, lateral, and dorsal views of silicified specimen, ×1.5, T6714, Root River Quarry (F141.8W); *9*, ventral exterior of calcareous specimen, ×1.5, T6713, Mahood's Creek (F192.145W). All from Prosser member, Galena formation. (p. 770)

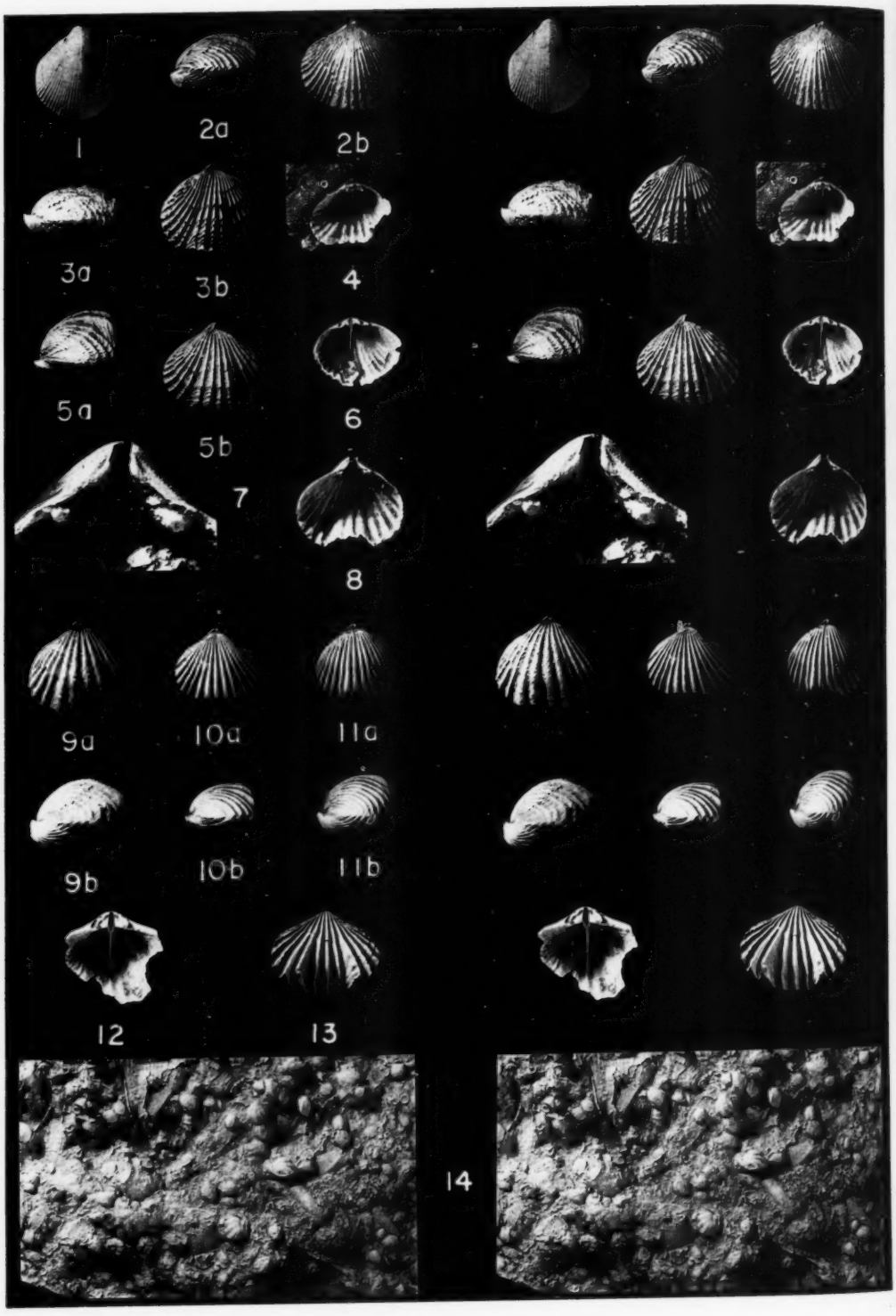
10—Oxoplecia ulrichi (Winchell & Schuchert). Interior of apical part of calcareous ventral valve, ×1, T6696, Dubuque formation, Lime City Quarry (F111.60S). (p. 769)

11a, b—Zygospira uphami, Winchell & Schuchert. Lateral and dorsal views of calcareous specimen, ×1.5, T6711, basal Stewartville member, Galena formation, Rifle Hill (F171.38W). (See Pl. 70, fig. 1). (p. 773)

12—Rhynchotrema ainsliei (Winchell). Detail of part of surface of calcareous specimen, ×5, T6697b, low Decorah formation, Fountain (North) (F96.21S). (p. 773)



Weiss, Ordovician brachiopods, Minnesota



Weiss, Ordovician brachiopods, Minnesota

16. Limestone; grayish-yellow, weathered from yellowish-brown, very fine-grained, even bed, pyritic. With *Protozyga nicolleti*, *Skenidioides anthonense*, and *Phyllodictya* sp. 6
15. Bentonite; pale yellowish-orange, unfossiliferous, underlain by abnormally thick fissile calcareous very pale yellow shale, with similar thin shale locally at the top. 4
14. Limestone; brownish-gray, very fine-grained, 1–2 moderately even beds, very poorly fossiliferous. With *Pionodema* fragments and numerous conodonts. 4
13. Shale; grayish-yellow, fissile, calcareous, unfossiliferous. 2
12. Limestone; pale yellowish-brown, very fine-grained and microgranular, even bed, very fragmental, poorly fossiliferous. With *Bumastus* sp., *Schmidtella* sp., and conodonts. 4–5
11. Shale; yellowish-brown, fissile, calcareous, unfossiliferous. ½

McGregor member: 15 feet 5 inches, yellowish to light olive gray microgranular crinkly-bedded limestone.

DECORAH FORMATION

This unit of yellowish-green calcareous shales, sparsely streaked with fossiliferous limy layers, thickens from about 20 feet at the Iowa line to nearly 90 feet at the Twin Cities. The members of the Decorah formation (Spechts Ferry, Guttenberg, and Ion) are not recognizable rock units in Minnesota.

GALENA FORMATION

The Galena formation in southeastern Minnesota comprises carbonate rocks that overlie the Decorah shales and underlie evenly interbedded limestones and shales of the Dubuque formation. It consists of thin crinkly beds that are bonded into massive units separated by the more conspicuous bedding planes, which character gives the formation a thick-bedded gross appearance. It consists of three members: Cummingsville (new), Prosser, and Stewartville, in stratigraphic order. The Cummingsville is interbedded limestone and shaly limestone, the Prosser is limestone, and the Stewartville is dolomitic limestone.

EXPLANATION OF PLATE 70

FIG. *1*—*Zygospira uphami* Winchell & Schuchert, Ventral exterior, ×1.5, of same specimen figured on Pl. 69, fig. 11a, b. (p. 773)

2a, b—*Rhynchotrema ainsliei* (Winchell). Lateral and dorsal views of complete shell, ×1, T6697a, low Decorah, Fountain (North) (F96.21S). (p. 773)

3–7—*Rhynchotrema increbescens increbescens* (Hall). *3a, b*, lateral and dorsal views of a complete shell showing only moderately the characters of the subspecies, ×1, T6698a; *4*, dorsal interior, ×1, T6698c (prominent blade of cardinal process does not show in photographic reproduction); *5a, b*, lateral and dorsal views of a specimen showing characters typical of the subspecies (cf. Pl. 70 fig. 3), ×1, T6698b; *6*, dorsal interior showing clearly the prominent cardinal process, ×1, T6701, middle Decorah formation (Bed 5 of Sardeson); *7*, interior of ventral apex showing gaping delthyrium bordered by rudimentary deltidial plates, ×5, T6698d. All specimens from the Sardeson collection; Decorah formation, Twin City Brick and Tile Company clay pit, at St. Paul; all except fig. 6 from upper part of Decorah (Bed 6 of Sardeson 1897). (p. 772)

8–11—*Rhynchotrema increbescens minnesotensis* (Sardeson). *8*, interior of silicified valve showing same features as in fig. 7, T6700, Guttenberg member, Decorah formation, (Bed 4 of Sardeson), Argyle, Wisconsin; *9a, b*, dorsal and lateral views of a typical specimen of the subspecies, T6699a; *10a, b*, dorsal and lateral views of another specimen from the same population, but flatter and wider than most individuals, T6699b; *11a, b* dorsal and lateral views of another specimen having an unusually strong fold for the subspecies, T6699c. Compare figs. 9–11 with 3 and 5. All specimens from the Sardeson collection; all except fig. 8 from the lower part of the Decorah formation (Bed 4 of Sardeson, 1897), Twin City Brick and Tile Company pit at St. Paul. All Views ×1. (p. 773)

13—*Rhynchotrema increbescens* var. *laticosta* Winchell & Schuchert. Ventral exterior of typical specimen, ×1, T6695b, Sardeson Collection, upper part of Decorah formation (Bed 6 of Sardeson, 1897), Twin City Brick and Tile Company pit at St. Paul. (p. 773)

14—*Protozyga nicolleti* (Winchell & Schuchert). Specimens on a slab of limestone, ×1, T6715a, from Carimona member, Platteville formation, Waterworks Hill (F149.21W). Demonstrates the variety of shapes and degree of costation of associated individuals. (p. 774)

The Cummingsville Member

Cummingsville is the name proposed for interbedded limestones and shaly limestones at the base of the Galena formation that were formerly included in the Prosser member. The name derives from the hamlet of Cummingsville, Olmsted County, Minnesota, on State Highway 30, 3.5 miles west of Chatfield. The type section is 0.5 miles north of Cummingsville, on the east edge of the SE¼ Sec. 21, T. 105 N., R. 12 W. The member is 63 feet thick at the type locality.

The Cummingsville is an argillaceous limestone, yellowish-gray to pale yellowish-brown, generally microgranular, thin and crinkly-bedded, with conspicuous to thick shaly partings. Thin beds are typically grouped into massive units that are separated by smoother, more prominent shaly bedding planes. When freshly exposed the unit appears thick-bedded. It is generally very argillaceous, most of the detrital fraction being in the shaly partings. The amount of detrital material varies cyclically throughout the unit so that, upon weathering, alternate units of shaly limestone and limy shale are developed, giving the outcrop a serrated profile. With advance of weathering the shaly units become thicker at the expense of the limestone units. This "sawtooth" character extends from within 8 feet of the base to within 15 feet of the top of the member at Cummingsville, but toward the southeast this feature is progressively restricted from the base upwards. There are no chert nodules or corrosion zones at the type locality. Southeastward from there a few zones of chert nodules appear in the lower part and above the middle. Two corrosion zones have been found midway between the chert zones in southeastern Fillmore County, but nothing more is known of their distribution.

The Cummingsville is not notably fossiliferous. *Resserella* and *Sowerbyella* are the dominant fossils, but they are not as abundant as they are in the Prosser member. Fossils are usually more numerous in the shaly units, although this fact may merely reflect greater ease of collecting. *Receptaculites* occurs throughout the member except close to the base, and defines the lower *Receptaculites* zone.

The base of the Cummingsville is the level at which the green shales of the Decorah formation are succeeded by rock that is predominatntly limestone, usually beds of lumpy or nodular limestone in a shale matrix. A veritable coquina, about 4 inches thick, of *Prasopora* and other bryozoans, occurs near the top of the 1 to 3 foot interval of nodular limestone and shale at the base of the member. This *Prasopora* concentrate in southeastern Minnesota probably is related to the *Prasopora* bed that marks the top of the Ion member of the Decorah formation in Iowa (Kay, 1929, p. 656). The brassy oölites typical of the top of the Decorah at some localities are rare in the basal Cummingsville.

At the top of the member the level of greatest change from a high detrital fraction to a low one (Cummingsville to Prosser) is closely approximated by a thin bed of sandy and silty limestone that is poorly fossiliferous, contains some phosphatic debris, and locally is very pyritic. This thin bed is arbitrarily designated the topmost bed of the member.

The Cummingsville shaly limestone is readily distinguished from the Decorah shale. It is distinguished from the Prosser member principally by a detrital content at least twice as great as that of the Prosser. The response to weathering is characteristic and distinct from that of the Prosser, and even on fresh faces the higher detrital content can be noted in the form of thicker shaly streaks and the earthy luster of the rock.

It is significant that Winchell and Ulrich (1897, p. cviii) recognized that the Galena consists of "three lithologic divisions, the Galena shales [Cummingsville rock], the middle Galena, a portion consisting principally of pure limestone [Prosser rock of this paper] and the upper Galena or *Maclurea* bed, a magnesian limestone [Stewartville rock]." Winchell and Ulrich did not emphasize this classification and it has since been ignored.

The insoluble fraction of the Cummingsville member ranges from about 5 to 25 percent, depending upon whether the samples are from the limestones or very shaly units; it averages 10 to 15 percent. Yellowish-

brown or yellowish-gray clays make up the bulk of the residues. Tiny cubes and aggregates of pyrite are almost always present. Conodonts and other phosphatic materials are scarce. Siliceous silt and very fine sand are commonly present, but in smaller relative amounts than in the Prosser member. Siliceous fossil debris is not as prevalent as in the Prosser; in fact is generally absent where the Cummingsville is not cherty. The rock is a calcarenite with abundant fossil debris and very minor amounts of dolomite.

The member is 63 feet thick at the type locality and is of essentially the same thickness elsewhere in southeastern Minnesota. The total extent of the member is not known, but it occurs throughout southeastern Minnesota and northern Iowa. It is probably not recognizable in the Platteville mineral district.

Cummingsville Section (F164)

Road cut and quarries from 0.2 to 0.7 miles north of Cummingsville, Olmsted County, Minnesota (east edge SE¼ Sec. 21, T. 105 N., R. 12 W.). The base of the section is the limestone of the Carimona member of the Platteville formation that abounds in *Protozyga nicolleti*. Only the Cummingsville member is here described in detail.

DUBUQUE FORMATION

The Dubuque formation comprises interbedded light olive gray limestones and light olive gray calcareous shales that lie above the yellowish Stewartville dolomitic limestone and below the yellowish argillaceous limestone of the Maquoketa formation. The Dubuque of this paper is essentially that of other authors.

Galena formation: 93 feet

Prosser member: 30 feet, yellowish-gray or yellowish-brown microgranular thin-bedded limestone with thin shaly partings.

Cummingsville member: 63 feet

		Feet	Inches
43.	Sandy limestone; brownish-gray, fine-grained, argillaceous, phosphatic, with much very fine-grained quartz sand and coarse silt, bonded to beds above and below, but has pitted top. With *Resserella rogata* and conodonts.		2
42.	Limestone; yellowish-gray, microgranular to very fine-grained, unfossiliferous, massive unit of thin crinkly beds with little shale in the partings.	1	8
41.	Limestone; yellowish-gray, microgranular, massive units of thin, crinkly beds, with prominent shale partings, argillaceous, burrowed. With *Resserella rogata* and *Sowerbyella minnesotensis*, and with *Receptaculites oweni* to within 5 feet of the top.	15	2
40.	Shaly limestone; very pale olive, microgranular, thin, crinkly-bedded, with thick shale partings, argillaceous. With *Resserella rogata* and *Sowerbyella minnesotensis*.		10
39.	Limestone; yellowish-gray to grayish-yellow, microgranular to very fine-grained, units of thin, crinkly beds with thin shale partings.	3	2
38.	Shaly limestone; dusky yellow, microgranular, thin, crinkly-bedded, with thick shale partings, very argillaceous, with several coquinoid layers. With *Dinorthis sweenyi*, *Glyptorthis bellarugosa*, *"Hebertella borealis,"* *Platystrophia amoena*, *Rafinesquina camerata*, *Resserella rogata*, *Sowerbyella minnesotensis*, *Aspidopora* sp., *Batostoma* sp., *Rhinidictya* sp., *Illaenus americanus*, *Sretptelasma corniculum*.	1	2
37.	Limestone; yellowish-gray, very fine-grained, thin, crinkly-bedded, with thin shale partings, bonded into a resistant ledge, burrowed. With *Sowerbyella minnesotensis*.		8
36.	Shaly limestone; yellowish-brown, microgranular to very fine-grained, thin, crinkly-bedded, with thick shale partings, less argillaceous than most such beds. With *Dinorthis sweenyi*, *Plectorthis plicatella trentonensis*, *Rhynchotrema increbescens increbescens*, *Resserella rogata*, *Sowerbyella minnesotensis*, *Prasopora* sp., *Bumastus billingsi*.	2	7
35.	Limestone; yellowish-gray, very fine-grained, ledge of thin, crinkly beds with thin shale partings.		9
34.	Shaly limestone; yellowish-brown, very fine-grained, with fine-grained coquinoid layers, thin, crinkly-bedded, with thick shale partings. With *Resserella rogata*, *Sowerbyella minnesotensis*, *Batostoma* sp.	1	8

	Feet	Inches
33. Limestone; yellowish gray, very fine-grained, ledge of thin, crinkly beds with thin shale partings.	2	2
32. Shale; grayish-yellow, thinly-laminated, calcareous, but without limy lenses, unfossiliferous.		10
31. Limestone; yellowish-gray, very fine-grained, ledge of thin, crinkly beds with thin shale partings, argillaceous, with burrows, with fine to medium-grained coquinoid layer near middle. With *Sowerbyella minnesotensis*, *Monotrypa* sp., and *Hormotoma bellicincta*.	2	2
30. Shaly limestone; yellowish-gray thin nodular beds of limestone in matrix of thick shale partings. With *Resserella rogata*, *Sowerbyella minnesotensis*, and *Salpingostoma* sp.	2	
29. Limestone; yellowish-gray very fine-grained ledge of thin, crinkly beds with thin shale partings.		8
28. Shaly limestone; grayish-yellow, thin, crinkly-bedded, with very thick shale partings.		10
27. Limestone; yellowish-gray very fine-grained ledge of thin, crinkly beds with thin shale partings, argillaceous.		11
26. Shaly limestone; yellowish-gray, very fine-grained, thin, crinkly-bedded, with thick shale partings, more calcareous than most such beds. With *Plectorthis plicatella trentonensis*.		10
25. Limestone; yellowish-gray very fine-grained ledge of thin, crinkly beds with thin shale partings.	1	2
24. Shaly limestone; grayish-yellow, very fine-grained, thin, crinkly-bedded, with thick shale partings, very argillaceous.	1	1
23. Limestone; pale orange very fine-grained ledges of thin, very crinkly beds with thin shale partings, argillaceous, thoroughly burrowed. With *Dinorthis sweenyi*, *Platystrophia amoena*, *Resserella rogata*, *Sowerbyella minnesotensis*, *Monotrypa* sp., *Streptelasma corniculum*, and *Receptaculites oweni*.	1	2
22. Limestone; yellowish-gray very fine-grained ledge of thin, crinkly beds with thin shale partings, thick shaly bedding plane at base, and yellowish-brown, locally crinoidal bed at top.	1	8
21. Limestone; yellowish-gray very fine-grained ledge of thin, crinkly beds with thin shale partings, argillaceous, shaly bedding plane at top, under which is grayish-orange-pink crinoidal and fossiliferous bed. With *Rhynchotrema increbescens increbescens*, *Vellamo americana*, and *Receptaculites oweni*.	2	
20. Shaly limestone; yellowish-gray, thin, crinkly-bedded, very argillaceous, with thick shale partings, with pale yellowish-brown fine-grained nodular fossiliferous streak near middle. With *Resserella rogata* and *Sowerbyella minnesotensis*.	1	
19. Limestone; light olive gray, very fine-grained, ledge of thin, crinkly beds with thin shale partings.	2	2
18. Shaly limestone; grayish-yellow, very fine-grained, thin, nodular, with thick shale partings, very argillaceous. With *Lingula* sp., *Strophomena* sp., *Vellamo americana*, *Batostoma* sp., and *Monotrypa* sp.	1	8
17. Limestone; light olive gray microgranular ledge of thin, crinkly beds with thin shale partings.	1	6
16. Shaly limestone; grayish-yellow, very fine-grained, thin, crinkly-bedded, thick shale partings, very argillaceous. With *Dinorthis sweenyi*, *Resserella rogata*, *Vellamo americana*, and *Aspidopora* sp.	1	8
15. Limestone; gravish-orange-pink, microgranular and very fine-grained, thin, crinkly-bedded, with thin shale partings, argillaceous. With *Resserella rogata* and *Sowerbyella minnesotensis*.	1	7
14. Shaly limestone; yellowish-gray, microgranular, thin, crinkly-bedded, with thick shale partings, very argillaceous.		8
13. Limestone; pale yellowish-brown, microgranular, massive unit of thin, crinkly beds with dark yellowish-brown shale partings, somewhat burrowed. With *Lingula* sp. *Resserella rogata*, and *Sowerbyella minnesotensis*.	7	
12. Limestone; pale yellowish-brown, microgranular and very fine-grained, thin, lumpy beds with shale partings, very argillaceous, especially in the lower half, with corrosion zone (?) at the top. With *Platystrophia trentonensis perplana*.		6

Decorah formation: 46 feet, greenish-gray calcareous shale with ferruginous oölites in the top three feet.

Platteville formation: 2 feet.

Carimona member: 2 feet, covered except for pyritic light olive gray limestone with abundant *Protozyga nicolleti*.

et Inches
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6

LOCALITIES

Except for localities of specimens from the F. W. Sardeson Collection, each locality is assigned a name and a number that is preceded by F in the text. Collections from these localities are designated by the locality number and by decimal numbers that indicate the number of feet above the base of the section. Collectors are indicated by a final initial: B—W. C. Bell; S—C. R. Stauffer; and W—M.P. Weiss. Illustrated specimens are in the collections of the University of Minnesota Geological Museum.

Carter' Creek (F93)—Exposures in the banks of Carter's Creek in the E½ of Sec. 9, T. 103 N. R. 12 W.

F93.35B—Decorah formation, 23 to 37 feet above the base of the formation.

Fountain (North) (F96)—Road cut on Highway 52 from 3.0 to 3.5 miles north of the RR underpass in Fountain (NE¼ Sec. 27, T. 104 N., R. 11 W.).

F96.21S—Decorah formation, basal 8 feet.

Gatzke Farm (F88)—Quarry in farmyard near center of NW¼ Sec. 25, T. 102 N., R. 11 W.).

F88.8W—Decorah formation, thick coquina ledge 2.5 feet above base of formation.

Lime City Quarry (F111)—Quarry and stream Cut on Deer Creek, 3.0 miles north of Spring Valley (NE¼ SE¼ Sec. 9, T. 103 N., R. 13 W.).

F111.60S—Dubuque formation; higher beds that provided most of the specimens are no longer exposed.

Mahood's Creek (F192)—Exposures in valleys of Spring Valley and Mahood's Creeks from NE¼ Sec. 17 to SE¼ Sec. 20, T. 103 N., R. 12 W.).

F192.145W—Galena formation, Prosser member, cherty beds from 27 to 48 feet above the base of the member (collection from W½ SW¼ Sec. 16, T. 103 N., R. 12 W.).

Myrah Quarry (F86)—Quarry and road cut 1.0 mile southeast of Spring Grove (SE¼ SW¼ Sec. 12, T. 101 N., R. 7 W.).

F86.0B—Decorah formation, basal 4 feet.

Pederson's Quarry (F87)—Quarry near middle of north edge of SW¼ Sec. 9, T. 101 N., R. 10 W.

F87.37W—Galena formation, Prosser member, 18.5 to 22.5 feet above the base of the member and 37 to 41 feet above the floor of the quarry.

Rifle Hill (F171)—Quarries and road cuts in Rifle Hill on west bank of Canfield Creek (NW¼ Sec. 35, T. 102 N., R. 12 W.).

F171.38W—Galena formation, Stewartville member, 7 feet above base of member.

Root River Quarry (F141)—Quarry on west bank of South Branch of the Root River, downstream from the stone-arch bridge (SW¼ Sec. 22, T. 102 N., R. 12 W.). Galena formation mid-portion of Prosser member.

F141.3W—Prosser member, 2.25 to 2.5 feet above floor of quarry.

F141.8W—Prosser member, 7.75 to 11 feet above floor of quarry.

Spring Grove Underpass (F85)—Road cut and quarries on Highway 44 at the RR underpass 3.2 miles west of Spring Grove (SE¼ SE¼ Sec. 17, T. 101 N., R. 7 W.).

F85.39B—Decorah formation, thick coquina ledge 6.25 feet above base of the formation.

F85.44B—Decorah formation, 8.25 to 13.25 feet above base of the formation.

F85.46B—Decorah formation, 13.25 to 15.25 feet above base of the formation.

Sugar Creek Annex (F146)—Road ditch at SW corner of Sec. 4, T. 103 N., R. 11 W.

F146W—Section not measured; collection from McGregor member of Platteville formation 3 feet below the bentonite in the Carimona member.

Waterworks Hill (F149)—Road ditch and quarry on Highway 74 on hill at east edge of Chatfield (N½ NW¼ Sec. 5, T. 104 N., R. 11 W.).

F149.21W—Platteville formation, Carimona member, 3.7 feet above the base of the member.

SYSTEMATIC DESCRIPTIONS

Phylum BRACHIOPODA
Class ARTICULATA
Superfamily ORTHACEA
Genus PLECTORTHIS Hall & Clarke 1892

PLECTORTHIS PLICATELLA (Hall)
Pl. 69, figs. 1 a, b

Orthis (*Plectorthis*) *plicatella* Hall, HALL & CLARKE, 1892, pp. 194, 221, pl. 5, figs. 18–20.
Plectorthis plicatella (Hall) SCHUCHERT & COOPER, 1932, p. 57, pl. 11, figs. 4, 9.

Discussion.—This species is well characterized and widely distributed. Some degree of multiplication of the costae is typical. In the Minnesota specimens multiplication by bifurcation is limited to a small region close to the beak. Although newly formed costae originate at the level of the floor of the grooves and rise upward, thus giving the false appearance of implantation, they actually do branch from the side of an old costa.

Occurrence.—Rare in the Cummingsville and lower Prosser members of the Galena formation. Occurs with and is dominated by the subspecies *P. p. trentonensis.*

PLECTORTHIS PLICATELLA TRENTONENSIS Foerste
Pl. 69, figs. 2–4

Orthis (*Plectorthis*) *plicatella* Hall, WINCHELL & SCHUCHERT, 1895, p. 436, pl. 33, figs. 5–7.

Plectorthis plicatella-trentonensis FOERSTE, 1910, p. 49; WILSON, 1946, p. 28, pl. 2, figs. 7a, b.

This subspecies differs from *P. plicatella* s.s. only in the absence of secondary costae. In the region close to the beak some costae are smaller than their neighbors, but all merge at the beak. The two subspecies can be distinguished with certainty only if the preservation is good. Some specimens of *P. plicatella* s.s. have produced secondary costae so close to the beak that the two subspecies intergrade in this character.

Occurrence.—Sparsely distributed through the Galena formation, but most numerous in the middle of the Prosser member, where it and *Dinorthis sweenyi* (Winchell & Schuchert) dominate the coquinoid layers that abound in orthid brachiopods.

PLECTORTHIS PLICATELLA MINNESOTENSIS Weiss, n. subsp.
Pl. 69, fig. 5, 6

This small subspecies is most similar to *P. plicatella trentonensis*, but differs from it in being only about half the size of that subspecies. The growth lines are particularly prominent, giving a pitted appearance to the grooves between the costae. A few specimens show a low secondary costella in the middle of each groove. These are like the secondary costellae found in triplicate in *P. triplicatella* (Meek). The interior is unknown.

Discussion.—This subspecies resembles *P. plicatella* var. *laurentina* Wilson (1946, p. 28), but does not have the abundance of costae of that variety. *P. p.* var. *laurentina* occurs with *P. p. trentonensis*, but *P. p. minnesotensis* and *P. p. trentonensis* do not occur together in Minnesota. The clarity of the growth lines and secondary costellae of *P. p. minnesotensis* may result from the fact that the valves are calcareous, whereas the good specimens of *P. p. trentonensis* are silicified. The similarity between the subspecies *P. p. trentonensis* and *P. p. minnesotensis*, and the fact that the latter preceded the former in time, suggest that *P. p. minnesotensis* is the precursor of *P. p. trentonensis*.

Occurrence.—Uncommon in the McGregor member of the Platteville formation and rare in the lower part of the Decorah formation.

Genus DOLEROIDES Cooper, 1930
DOLEROIDES PERVETUS (Conrad)
Pl. 71, figs. 1, 2

Orthis (*Dalmanella*) *subaequata* var. *perveta* Conrad, WINCHELL & SCHUCHERT, 1895, p. 450, pl. 33, figs. 40–42.
Hebertella (*Doleroides*) *pervetus* (Conrad) COOPER, 1930, p. 381, pl. 35, fig. 8; pl. 36, figs. 4, 7; pl. 37, figs. 1, 3, 13.
Doleroides pervetus (Conrad) SCHUCHERT & COOPER, 1932, pl. 11, figs. 10, 12, 13.

This species is variable in many respects. It may be moderately to markedly transverse. The costellae are usually coarser than those of *Pionodema subaequata*, but are nearly as fine on some specimens. Sometimes the costellae occupying the median quarter or third of the shell are somewhat coarser than the others. The shells range from rectimarginate to distinctly uniplicate, and there is no apparent trend of this quality upward through the rocks. The older and/or larger shells are uniplicate. The thickness or gibbosity of the shells shows no constant relation to other characters or to stratigraphic horizon.

In some respects *D. pervetus* s.s. merges into the subspecies *D. p. gibbosus*. The two together form a large population with individual variations of several types, but none sufficiently constant or conspicuous to justify division into species. The subspecies *D. p. gibbosus* is recognized for the reasons given in the discussion of that subspecies.

Discussion.—Forms agreeing with *D. pervetus ottawanus* Wilson (1932, 1946), and others even smaller and less sharply folded, are part of the continuum of forms that make up collections of *D. pervetus* s.s. from Minnesota. *D. pervetus ottawanus* is not recognized here because the form has no environmental or temporal significance in Minnesota. Wilson's holotype and paratypes (1932, pl. 1, figs. 3–5) suggest that her collections include a similar range of forms.

Occurrence.—Common in the Carimona member of the Platteville formation and the lower and middle parts of the Decorah formation. Rare in the upper Decorah.

DOLEROIDES PERVETUS GIBBOSUS (Billings)
Pl. 71, figs. 3 a-f

Orthis (*Dalmanella*) *subaequata* var. *gibbosa* Billings, WINCHELL & SCHUCHERT, 1895, p. 451.

not pl. 33, figs. 43–45 (see Cooper, 1930, p. 379).

Hebertella (Doleroides) gibbosus (Billings) Cooper, 1930, p. 382, pl. 35, figs. 5–7, 14; pl. 37, fig. 2.

Doleroides gibbosus (Billings) Schuchert & Cooper, 1932, pl. 11, figs. 6–8, 11, 16, 18.

The most characteristic specimens of this subspecies differ from *D. p. pervetus* in a somewhat greater length/width ratio, more prominent dorsal fold and ventral sulcus, and, sometimes (e.g. Pl. 71, fig. 3c) a shorter hinge line. The subspecies is gradational with *D. p. pervetus* in all these respects. The specimen in Pl. 71, fig. 3c may be regarded as the extreme development of these tendencies.

Here again the prominent folds and sulci are usually on the older and/or larger shells. The costellae on the fold and, particularly, those in the sulcus are commonly coarser than the others.

Discussion.—The individuals of the genus *Doleroides* in the Ordovician rocks of Minnesota make up a single population containing a number of variations of differing intensities. Soon after their appearance in the rocks conditions were favorable for abundant and luxuriant growth. It was then that the large fat uniplicate shells dominated the population. The subspecies *D. p. gibbosus* is recognized here in order to direct attention to that fact, and because the genus is founded on some specimens of this type from the Decorah formation of Minnesota.

Occurrence.—Abundant in the coquinoid layers near the base of the Decorah formation, but dominated by *Pionodema subaequata*. The subspecies *D. p. gibbosus* is not distinguished from *D. p. pervetus* in the measured sections.

Superfamily Dalmanellacea
Genus Pionodema Foerste, 1912
Pionodema subaequata (Conrad)
Pl. 71, fig. 4a-f; Pl. 72, fig. 1–7

Orthis (Dalmanella) subaequata Conrad, Winchell & Schuchert, 1895, p. 446, pl. 33, figs. 30–36.

Orthis (Dalmanella) amoena Winchell, Winchell & Schuchert, 1895, p. 453, pl. 33, figs. 48–49.

Pionodema subaequata (Conrad) Cooper, 1930, p. 378, pl. 35, fig. 4, pl. 36, figs. 1, 3. pl. 37, fig. 6.

Pionodema uniplicata Cooper, 1930, p. 379, pl. 35, figs. 1, 2.

Pionodema minnesotensis Cooper, 1930, p. 379, pl. 36, fig. 14.

This species exhibits a wide variety of shapes, gibbosity, and degree of plication, found within collections from single beds and coquinas. A variety of illustrations from large collections is given in order to demonstrate this fact.

The species grades downward into small forms approaching *P. conradi* (Winchell) and upward into the rare *P. circularis* (Winchell).

Occurrence.—Numerous in the Carimona member of the Platteville formation and the middle Decorah formation. It is rare in the upper Decorah, where it occurs with *P. circularis*. In the lower Decorah it dominates the fauna and occurs almost to the exclusion of inorganic matter in many coquinoid layers.

Superfamily Triplesiacea
Genus Oxoplecia Wilson, 1913
Oxoplecia ulrichi (Winchell & Schuchert)
Pl. 69, fig. 10

Triplecia ulrichi Winchell & Schuchert, 1895, p. 409, text-fig. 34 a–e.

A broken ventral valve is figured merely as a contribution to the literature on the species. Dorsal cardinalia are so very delicate that it was impossible to photograph a complete set.

Occurrence.—Very rare in the Dubuque formation, making it a poor zonal marker.

Superfamily Syntrophiacea
Genus Camerella Billings, 1859
Camerella panderi Billings
Pl. 69, figs. 7a-c

Camerella panderi Billings, Wilson, 1946, p. 118, pl. 11, fig. 2.

To the writer's knowledge this species has never before been recorded from Minnesota except in a faunal list by Stauffer & Thiel (1941, p. 235). The few specimens found agree with *C. panderi*, and are discussed and illustrated here merely to call attention to their presence in Minnesota. No preparation of the specimens was made in order to determine the question of generic assignment. Although Schuchert & Cooper (1932, p. 168) have suggested that the species is really a spiriferid, the exterior is

not similar to those of known spiriferids from the Minnesota Ordovician.

Although the generic names *Camerella* and *Parastrophina* are both used here, the writer is strongly of the opinion that genera should not be distinguished upon such minute characters as the presence or absence of alae on the cruralium (Ulrich & Cooper, 1938, p. 248), particularly when they are so closely similar in all other characters.

Occurrence.—Rare in the lower part of the Decorah formation.

Genus PARASTROPHINA Schuchert & Levene, 1929

PARASTROPHINA HEMIPLICATA (Hall)

Pl. 69, figs. 8–9

Anastrophia? hemiplicata (Hall) WINCHELL & SCHUCHERT, 1895, p. 382, pl. 30, figs. 29–31.
Anastrophia? hemiplicata var. *rotunda* WINCHELL & SCHUCHERT, 1895, p. 383, pl. 30, figs. 32–35.
Anastrophia? scofieldi WINCHELL & SCHUCHERT, 1895, p. 383, pl. 30, figs. 24–28.

This species is not only uncommon in Minnesota, but it is usually variable. The valves range from nearly round in plan view to wider than long, which is the common form. The thickness varies considerably from specimen to specimen. The costation, the only conspicuous external feature, is most variable of all. It is irregular on single valves, commonly giving them a distorted appearance. Not only do the half-costae differ in size on single specimens, but there may be more on one side than on the other (see Pl. 69, fig. 8a). Likewise, the length of the costae is not constant.

The specimens of this species are too rare to permit domonstration of the identity and purity of populations characterized according to some of the individual variants that may be found.

Occurrence.—Uncommon through the Cummingsville and Prosser members of the Galena formation. The species is most numerous in the middle Prosser, but only occasionaly specimens are found even there.

Superfamily RHYNCHONELLACEA
Genus RHYNCHOTREMA Hall, 1860

This genus was named by Hall (1860, p. 68) as a subgenus of *Rhynchonella* with *R. increbescens* Hall as the type species by monotypy. He had earlier figured (1847, pl. 33, fig. 13 and pl. 79, fig. 6) a number of specimens under that name. Of the "Trenton" specimens (p. 146, pl. 33) figs. 13a to 13o appear to represent one species, although 13g to 13o are larger. Figs. 13p to 13s are possibily of another species, but are ignored here because of the uncertainty. Figs. 13t to 13y are probably of the species *R. capax* Conrad. Hall's specimen from the "Hudson River" (p. 289, pl. 79, fig. 6) is poorly figured. Hall stated in the errata (1847, p. 339) that his *R. increbescens*, 1847, is probably equal to *R. capax* Conrad, 1842. Actually Hall's array of figures in-

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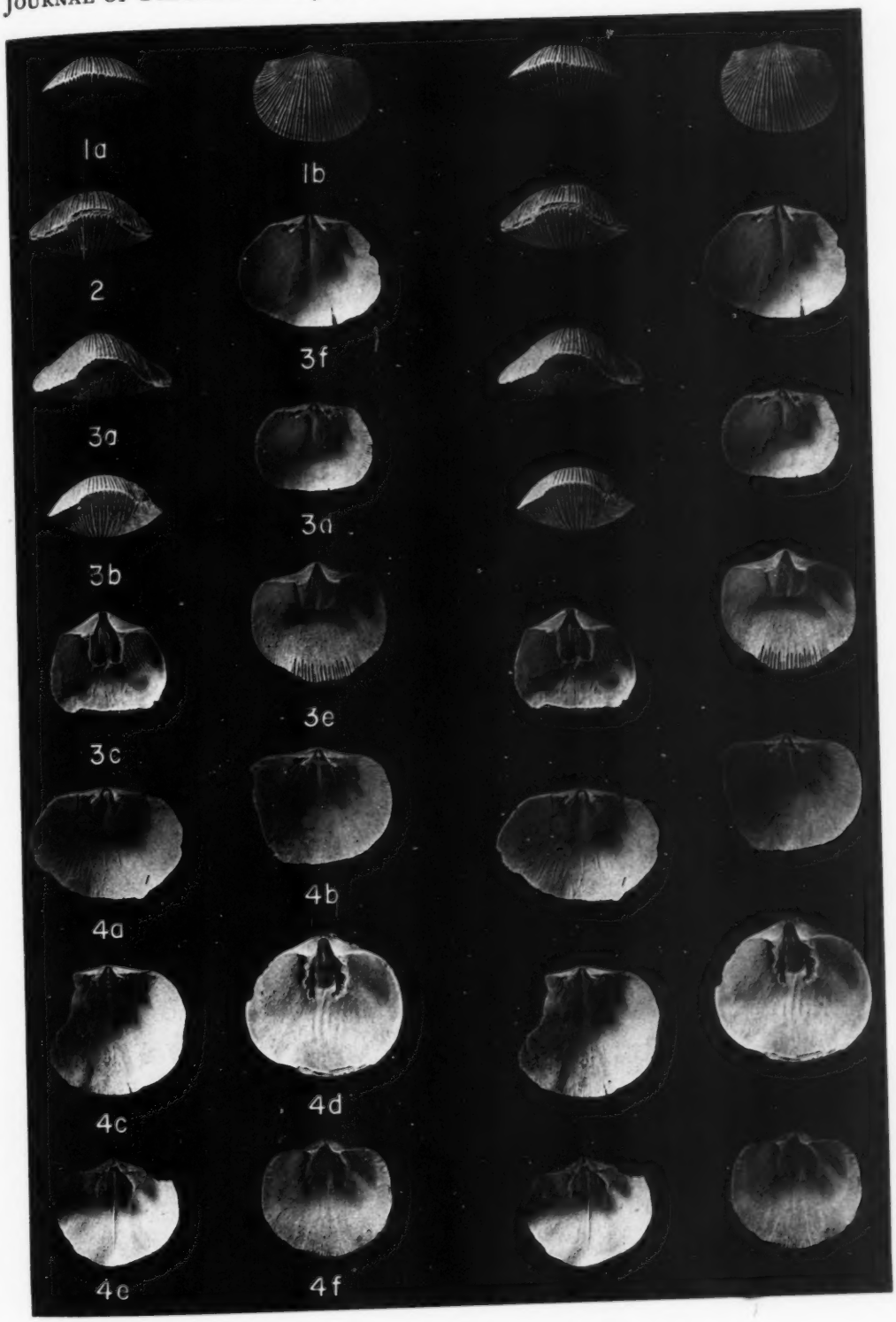
EXPLANATION OF PLATE 71

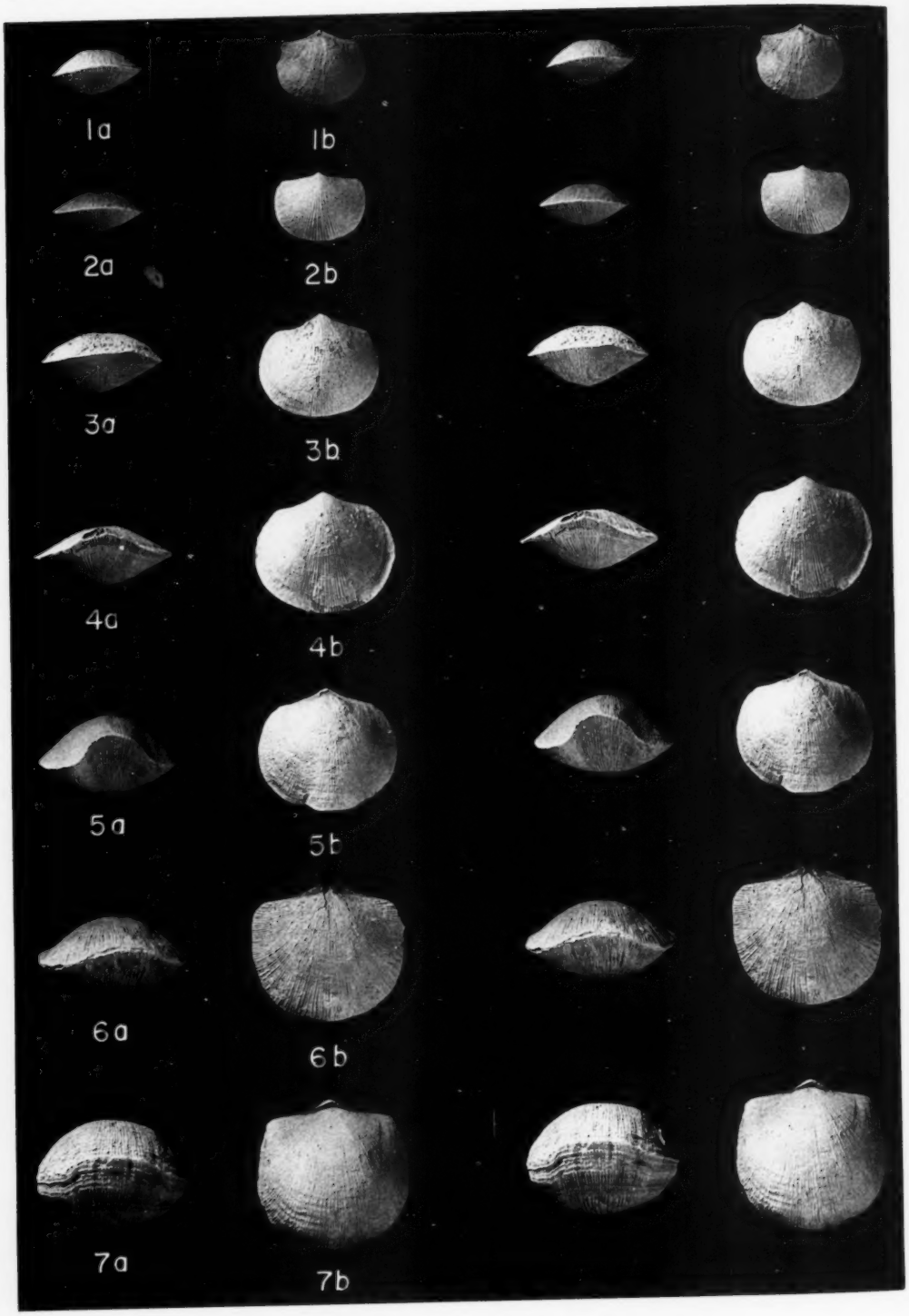
FIGS. *1, 2—Doleroides pervetus* (Conrad). *1a, 1b*, anterior and dorsal views of complete shell, T6716, middle Decorah formation, Carter's Creek (F93.35B); *2*, anterior view of complete shell, T6725, lower Decorah formation, Fountain (North) (F96.21S); all ×1. (p. 768)

3a–f—Doleroides pervetus gibbosus (Billings). *3a*, anterior view of typical specimen showing degree of plication, T6724a; *3b*, anterior view of specimen showing very weak plication, T6724b; *3c*, ventral interior of specimen displaying characters typical of the subspecies, T6724c; *3d*, dorsal interior of valve having a prominent fold, T6724d; *3e*, ventral interior of valve typical of subspecies, T6724e; *3f*, dorsal interior of valve somewhat larger and less strongly plicate than the most extreme forms, T6724f. All views ×1. All specimens from bed one foot thick in lower part of Decorah formation, Spring Grove underpass (F85.39B). (p. 768)

4a–f—Pionodema subaequata (Conrad). *4a*, dorsal interior of gerontic valve with much callus deposit in posterior part and with unusually prominent pallial markings, T6723a; *4b*, dorsal interior typical of species; slight forward tilting of the valve makes it appear somewhat like *Doleroides*, T6723b; *4c*, dorsal interior of large specimen with fold somewhat stronger than most, T6723c; *4d*, ventral interior of gerontic valve with thick callus deposits, T6723d; *4e* ventral interior showing well-developed median septum and adductor ridge, T6723e; *4f*, ventral interior representing the average or usual form of the species; note the broad adductor track, T6723g. All views ×1. All specimens from bed one foot thick in lower part of Decorah formation, Spring Grove underpass, (F85.39B). (p. 769)



Weiss, Ordovician brachiopods, Minnesota



Weiss, Ordovician brachiopods, Minnesota

cluded at least two species: *R. capax* and another that must therefore bear the name of *R. increbescens*. Wang (1949, p. 11) selected the specimen illustrated by Hall's figs. 13c, d as the type of *R. increbescens*.

However, many authors (listed by Wang) accepted Hall's statement in the errata and cited *R. capax* as the type species of the genus. Winchell & Schuchert (1895), however, did not make this error.

The problem became more complex when Hall again figured (1860, pp. 66–67, figs. 6–14) specimens of both *R. capax* and *R. increbescens* under the name of *R. increbescens*. Figs. 6–8 are not *R. capax*, and, although apparently new, they are very like figs. 13a–o of the 1847 report. Fig. 7 is the fig. 13n and fig. 8 the fig. 13o of the 1847 report. Figs. 9–14 are of *R. capax*.

With these citations as a background, the history of the genus *Rhynochotrema* and its type species can be summarized:

1. *R. increbescens* is the type species of *Rhynchotrema* by monotypical original assignment.
2. Hall's specimens and figures both in 1847 and 1860 included at least two morphologic groups, *R. capax* and *R. increbescens*.
3. Although Winchell & Schuchert (1895) have some of Hall's figures confused (in my opinion) they were the only ones prior to Wang who recognized the distinction between *R. capax* and *R. increbescens* in Hall's two works.
4. Hall's description of the species *R. increbescens* is broad enough to include both it and *R. capax*, and is based on exteriors.
5. Hall's description of the characters of *Rhynchotrema*, based on interiors, was made from specimens of *R. capax*. Notwithstanding, *R. increbescens* is the type species regardless of whether its interior agrees with that of *R. capax* (as Hall obviously believed, but did not know).
6. Until Wang (1949) the genus *Rhynchotrema* stood on *R. increbescens* (contrary to auct.) and included interiors of the *R. capax* type.
7. Ulrich & Cooper (1942, pp. 624, 625) amended the genus *Rhynchotrema* as follows:
   a) Proposed the genus *Ancistrorhyncha* for species with the following characters:
      open delthyrium
      strong dental plates
      costellate [contra *Rhynchotrema*]
      no median spetum [contra *Rhynchotrema*]
      no cruralium [sic] [contra *Rhynchotrema*]
   b) Proposed the genus *Rostricellula* for species with the following characters:
      costate
      delthyrium open or partly closed
      strong dental plates
      small cruralium [sic]
      strong median septum
      no cardinal process [contra *Rhynchotrema*]

EXPLANATION OF PLATE 72

FIGS. *1–7*—*Pionodema subaequata* (Conrad). Group of specimens (all ×1) showing range of shape, size, and plication exhibited by this species. *1a, b*, anterior and dorsal views of a small specimen, a type that is fairly common. It is inferred that the fold and sulcus, when developed, are a feature of late maturity or old age (see also fig. 5), T6727f. *2a, b*, anterior and ventral views of specimens with unusually fine costellae, T6727e. *3a, b*, anterior and ventral views of specimen typical of the species, T6727d. *4a, b*, anterior and ventral views of specimen with typical outline, but somewhat thinner than usual, T6727c. *5a, b*, anterior and dorsal views of strongly plicate specimen of type that is neither typical nor uncommon. This represents the maximum of plication seen in the species, and presumably is the *P. uniplicata* of Cooper (1930), T6727b. *6a, b*, anterior and dorsal views of large specimen with an unusually long hinge, This is the variant called *P. minnesotensis* by Cooper, T6727a. *7a, b*, anterior and dorsal views of bulbous and presumably gerontic specimen. This extreme form is rare, but one or two were found in the population from each of three localities, T6726, Spring Grove underpass (F85.46B). All specimens from basal part of Decorah formation; all except fig. 7 from Myrah Quarry (F86.0B). (p. 769)

not lamellose [contra *Rhynchotrema*]

c) Restricted *Rhynchotrema* to species with the following characters:
costate and lamellose
delthyrium open or partly closed
large median septum
simple cardinal process
small cruralium [sic]

8. Wang (1949, p. 11) restricted *Rhynchotrema* to his so-called *increbescens*-type, characterized by the following:
small open delthyrium
dental plates (p. 11 "rudimentary")
dental plates (p. 12 "well-developed")
cardinal process questionable, but the median septum is thickened posteriorly
no "cruralium" (inference only, not so stated by Wang)
He also placed *R. capax* and other gibbous or highly folded species in the genera *Lepidocyclus* and *Hypsoptycha* because the specimens of *R. increbescens* from New York " . . . show very peculiar characters as compared with those of *R. capax*" (p. 11). Wang failed to describe the peculiar characters.
9. *Conclusion*—Primitive rhynchonellids were not encountered in southeastern Minnesota so no comments can be offered on *Ancistrorhyncha*.

The genus *Rostricellula* is founded only upon a smooth surface and the absence of the cardinal process. Rhynchonellids generally are more or less lamellose when fresh, but smooth if weathered. From older to younger there is a trend of development and enlargement of the cardinal process. In southeastern Minnesota the cardinal process first appears in the Platteville or lower Decorah formations. The only interiors available to me from the lower part of the section were among silicified material collected by Sardeson from "Upper Buff" (Magnolia?) beds at Browntown, Wisconsin. They have no cardinal process, but possess a roughened septalium (referred to as a cruralium by Ulrich and Cooper). Exept for the apparent lack of a cardinal process these values are like the *R. increbescens* found in southeastern Minnesota. On a given valve the presence or absence of the cardinal process may be determined by the type of preservation, particularly on those having newly and poorly developed processes. I prefer to include in *Rhynchotrema* species that are elsewhere assigned to *Rostricellula*. Wang's remarks on *Rostricellula* (1949, p. 11) serve only to underscore the similarity between the two genera as proposed.

The species *Rhynchotrema*(?) *capax* (Conrad) occurs in the Upper Ordovician and is beyond the scope of this paper. The genus *Lepidocyclus* Wang 1949 may be justified on the basis of the fully closed delthyrium and the habit of thickening about the dental plates so as to obscure them, but it should be realized that it is gradational with *Rhynchotrema* and contains some progressive features that had their beginnings in the species of older rocks.

RHYNCHOTREMA INCREBESCENS INCREBESCENS (Hall)
Pl. 70, figs. 3–7

Rhynchonella increbescens HALL, 1847, p. 146, pl. 33, figs. 13c, d.
Rhynchotrema inaequivalvis (Castelnau) WINCHELL & SCHUCHERT, 1895, p. 459, pl. 34, figs. 12–14, 20–23, and 24? 25?.
Rhynchotrema wisconsinense FENTON & FENTON, 1922, p. 71, pl. 1, figs. 6–8.

This species has been well described elsewhere. Here it is only intended to distinguish *R. increbescens increbescens* from the subspecies *R. i. minnesotensis*, into which it grades. The most characteristic specimens of *R. increbescens* s.s. have the following features:
wider than long
16–22 costae
more or less high fold and deep sulcus
strong growth lines
dorsal valve high in front, ventral valve rather flat; giving a triangular profile.

The subspecies *R. i. increbescens* grades into the subspecies *R. i. minnesotensis* in all these characters. Within collections from a single bed may be found specimens that have one or more characters of typical specimens of each of the subspecies. It is believed that this transition from typical *R. i. minnesotensis* to typical *R. i. increbescens* can best

be expressed by making each a subspecies of *R. increbescens*.

Occurrence.—Middle Decorah formation to the upper part of the Prosser member of the Galena formation. The species is common only in the Decorah and, in fact, is almost rare in the Galena. Rare specimens from the Stewartville member are poorly preserved, but appear to belong to *R. increbescens*. *Rhynchotrema increbescens* var. *laticosta* Winchell & Schuchert (see Pl. 70, fig. 13) occurs rarely in the Decorah at St. Paul, and a single specimen was found in the middle Prosser in Fillmore County.

RHYNCHOTREMA INCREBESCENS MINNESOTENSIS (Sardeson)
Pl. 70, figs. 8–11

Rhynchonella minnesotensis SARDESON, 1892, p. 333, pl. 4, figs. 21–23.
Rhynchotrema inaequivalvis (Castelnau) WINCHELL & SCHUCHERT, 1895, p. 459, pl. 34, figs. 9–11, 15-17.
Rhynchotrema minnesotense (Sardeson) FENTON & FENTON, 1922, p. 70, pl. 1, figs. 15–17,
Rhynchotrema cuneiforme FENTON & FENTON 1922, p. 72, pl. 1, figs. 12–14.
Rhynchotrema missouriense FENTON & FENTON, 1922, p. 73, pl. 1, figs. 22–26.

This subspecies appeared earlier than *R. increbescens* s.s. and grades into it in all characters. The most characteristic specimens have the following features:

width less than or about equal to the length
12–14 costae; fewer on the Platteville specimens than on those from the Decorah
gently plicate, usually with low fold and shallow sulcus
inconspicuous growth lines
rather globose shell; profile is rounded to rectangular.

In illustrating the subspecies of *R. increbescens*, specimens from Sardeson's personal collection were used in order to take advantage of his own identifications.

Occurrence.—Platteville formation and lower and middle parts of the Decorah formation.

RHYNCHOTREMA AINSLIEI (Winchell)
Pl. 69, fig. 12; Pl. 70, fig. 2

Rhynchotrema ainsliei (Winchell) WINCHELL & SCHUCHERT, 1895, p. 459, pl. 34, figs. 1–8.

This species has been well described elsewhere except or the character of the growth lines. The edges of the growth lamellae have tiny bumps at small intervals. Because the growth lines are closely spaced the entire shell is finely pustulose.

No interiors were available for study.

Occurrence.—Uncommon in the lower and middle portions of the Decorah formation. A single specimen has been found in the Carimona member at Rochester, Minnesota.

Superfamily SPIRIFERACEA
Genus PROTOZYGA Hall & Clarke, 1894
PROTOZYGA NICOLLETI (Winchell & Schuchert)
Pl. 70, fig. 14

Hallina nicolleti WINCHELL & SCHUCHERT, 1895, p. 474, pl. 34, figs. 59–64.
Protozyga nicolleti (Winchell & Schuchert) COOPER, 1944, p. 317. pl. 120. figs. 52, 53.

A figure of a slab of limestone crowded with this species is included in order to show the range of shape and costation that occurs in the species. In outline the specimens range from longer than wide to about equidimensional. Most show faint costation along the anterior margin, but some are markedly costate in the anterior third. The costate group may be the precursor of *Cyclospira bisulcata* (Emmons) of the Galena formation.

Occurrence.—Throughout the Platteville formation, but abundant in and characteristic of the Carimona member. Rare in the lower Decorah.

Genus ZYGOSPIRA Hall 1862
ZYGOSPIRA UPHAMI Winchell & Schuchert
Pl. 69, fig. 11; Pl. 70, fig. 1

Zygespira uphami WINCHELL & SCHUCHERT, 1895, p. 468, pl. 34, figs. 45–48.

This species is included for the sake of illustration. The generic assignment is tentative, although the exterior is closer to *Zygospira* than *Catazyga*. Furthermore, serial sections of five specimens show no evidence of a jugum or multiple spire. Apparently there is only a simple loop and spire system intermediate between those of *Protozyga nicolleti* and *Zygospira modesta* (Say).

Occurrence.—Rare in the lower part of the Stewartville member of the Galena formation.

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PALEONTOLOGY OF NORTHWESTERN VERMONT. V. THE LOWER CAMBRIAN FAUNA

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ABSTRACT—A synonymic catalog of all described species of Lower Cambrian fossils from northwestern Vermont lists 43 recognized species and genera. In addition, all taxonomic combinations known to have been applied in Vermont are reviewed and their present disposition indicated, where possible. As far as could be determined, the location of the type specimens, the type locality and the stratigraphic range in northwestern Vermont is given for each species. One new species, *Austinvillia billingsi*, is described.

INTRODUCTION

THIS article is a synonymic catalog of all species known or identified from the Lower Cambrian of northwestern Vermont. Only one new species, *Austinvillia billingsi*, is formally named, for these were among the most intensively studied of the North American Cambrian faunas in the early days, and recent collections have not added much to the fauna, although the genera *Prozacanthoides* and *Zacanthopsis*, not previously reported, are now recognized from indeterminable species.

No attempt is made to illustrate all species, for many have been figured by Resser (1937) and Resser & Howell (1938), and for others no specimens were available; but species are discussed or new figures are given where such illustration or discussion is felt to be useful. A few genera have been discussed, but not all, for this is intended primarily as a catalog of the species. For the same reasons the classification of the species is not considered.

All names are listed alphabetically by genus, and all abandoned names are given for cross-reference. All species known to have been referred at any time to the Lower Cambrian of northwestern Vermont are listed, even though some of the species are now assigned a younger age. In addition, there are listed several species that may with good reason be regarded as *not* present in northwestern Vermont although identified there by earlier workers; for these, only a brief synonymy is given, consisting principally of the original citation and those articles that identified the species in Vermont.

Following is a list of the forms I believe can be regarded as certainly belonging to the Lower Cambrian fauna of northwestern Vermont:

Anomalocaris? emmonsi
Antagmus typicalis
A.? simplex
Austinvillia billingsi (new)
Bathynotus holopygus
Billingsaspis adamsii
B. walcotti
Bonnia bubaris
B. capito
Bonniella desiderata
Dactyloidites asteroides
D. edsoni (=*D. asteroides?*)
Emmonsaspis? cambrensis
Eocystites
Hyolithellus? sp. indet.
Hyolithes americanus
H. sp. indet.
Kootenia marcoui
Kutorgina cingulata
Leptomitus zitteli
Nisusia festinata
N. transversa
Olenellus brachycephalus
O. hermani
O. thompsoni
O. vermontanus
Pagetides parkeri
Paterina labradorica swantonensis
Perimetopus arenosus
Periomma typicalis
Planolites virgatus
Protocaris marshi
Protypus hitchcocki
Prozacanthoides sp. indet. (new)
Ptychoparella teucer

P.? kindlei
Salterella sp. indet.
Swantonia antiquata
Tuzoia vermontensis
Wimanella? orientalis
Zacanthopsis sp. indet. (new)
Undetermined brachiopod (new)
Undetermined gastropod (new)

The five forms labelled (new) have not previously been reported from the area under any combination of names and are the only additions to the fauna. The absence from this list of such names as *Bonnia swantonensis*, *Paedeumias transitans* and *Rustella edsoni* is the effect of my personal opinion regarding the validity of these species.

The geographic and stratigraphic location of all fossil localities mentioned in this paper has been given in detail elsewhere (Shaw, 1954) and is not repeated here, but the stratigraphic range and the type locality are given in this paper for each species for which they are known.

ACKNOWLEDGMENTS

I am indebted to the following persons for their assistance in the completion of this paper: W. A. Bell advised me on the whereabouts of some of Elkanah Billings' types; G. A. Cooper supplied the photograph of *Protypus hitchcocki* reproduced as Pl. 74, fig. 9; Otto Haas loaned types figured by Whitfield and supplied information on some of Hall's types; Christina Lochman Balk criticized the partly completed manuscript; Franco Rasetti discussed the species *Pagetides parkeri* with me. The late P. E. Raymond loaned his collections for study and comparison. In addition, the following people assisted in my unsuccessful search for some of Ebenezer Emmons' types: R. C. Ramsdell, F. B. Van Houten, S. W. Lowman, J. L. Rosenholtz, and Winifred Goldring.

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SYNONYMIC CATALOG

Acrocephalites? vulcanus (see **Periomma typicalis**)

ANOMALOCARIS? EMMONSI (Walcott), 1886 (Crustacean)

Climacograptus?? emmonsi WALCOTT, 1886, U. S. Geol. Survey Bull. 30, pp. 93–94, pl. 11, fig. 5.
Climacograptus emmonsi MILLER, 1889, North American Geology and Palaeontology, p. 178, Cincinnati, Ohio.
Climacograptus?? emmonsi WALCOTT, 1891, U. S. Geol. Survey 10th Ann. Rept., pt. 1, p. 605, pl. 59, fig. 4.
Anomalocaris? emmonsi RESSER & HOWELL, 1938, Geol. Soc. America Bull., vol. 49, p. 232.

This crustacean is known only from a single specimen, poorly preserved, and it has not been figured photographically.

Holotype.—USNM 92727 (fide Resser & Howell).

Type and only known locality.—Parker quarry, probably about 150 feet above the base of the Parker slate.

Anomocare Tucer (see **Ptychoparella teucer**)
Antagmus adamsi (see **Billingsaspis adamsii**)

ANTAGMUS? SIMPLEX Resser, 1937 (Trilobite)

Ptychoparia vulcanus WALCOTT, 1886 (part), U. S. Geol. Survey Bull. 30, pp. 198–199, pl. 26, fig. 4a only. Fig. 4 = *Periomma typicalis*. —, WALCOTT, 1886 (part), U. S. Geol. Survey 10th Ann. Rept., pt. 1, p. 653, pl. 96, fig. 4a only. Fig. 4 = *Periomma typicalis*.
Antagmus? simplex RESSER, 1937, Jour. Paleontology, vol. 11, p. 54, pl. 8, figs. 54, 55. —, LOCHMAN, 1947, Jour Paleontology vol, 21, p. 63.

Resser has supplied the best illustrations of this species, which is characterized by its abruptly truncated glabella. It is probably not an *Antagmus*.

Syntypes.—USNM 65006 (fide Resser, 1937).

Type and only known locality.—Billings' Locality B, "1 mile east of Highgate Springs," 1000 to 1200 feet below top of Dunham dolomite.

Antagmus teucer (see **Antagmus typicalis**)

ANTAGMUS TYPICALIS Resser, 1937 (Trilobite)

Ptychoparia teucer WALCOTT, 1886, U. S. Geol. Survey Bull. 30, pp. 197–198, pl. 26, fig. 3. ——, WALCOTT, 1891, U. S. Geol. Survey 10th Ann. Rept., pt. 1, p. 652, pl. 96, fig. 3.
Antagmus teucer RESSER, 1936, Smithsonian Misc. Coll., vol. 95, no. 4, p. 4.

Antagmus typicalis RESSER, 1937, Jour. Paleontology, vol. 11, p. 54, pl. 8, fig. 64. ——, LOCHMAN, 1947, Jour. Paleontology, vol. 21, p. 62. ——, KINDLE & TASCH, 1948, Canadian Field-Naturalist, vol. 62, p. 138, pl. 3, figs. 5, 6.
[not] *Conocephalites teucer* BILLINGS, 1861 (see this paper under *Ptychoparella teucer*)

For a discussion of this and other Vermont ptychopariid trilobites see the comments under *Billingsaspis*.

Holotype.—USNM 15436 (fide Resser, 1937).

Type locality.—Locality B, "1 mile east of Highgate Springs", about 1000–1200 feet below the top of the Dunham dolomite (Shaw, 1954, p. 1036).

Stratigraphic range.—From the type locality to 50–100 feet above the base of the Monkton quartzite. By error, this species was omitted from the list of species in the Monkton quartzite in my previous summary (Shaw, 1954, p. 1044).

Apus marshi (see **Protocaris marshi**)

ATOPS TRILINEATA Emmons, 1844
(Trilobite)

Atops trilineata EMMONS, 1844, The Taconic System, p. 20. fig. 8, Albany, New York.
Ptychoparia trilineata WALCOTT, 1886, U. S. Geol. Survey Bull. 30, pp. 203–205, pl. 27, figs. 1, 1a, 1c.
Conocoryphe trilineata WALCOTT, 1887, Am. Jour. Sci., 3d ser., vol. 34, p. 197, pl. 1, figs. 7, 7a–b.
Ptychoparia trilineata WALCOTT, 1912, U. S. Geol. Survey Mon. 51, vol. 1, p. 251.

Walcott listed this species from USNM Loc. 319 in 1912; but nothing I have seen confirms its presence in the St. Albans area, and Dr. Howell (letter, July, 1949) has expressed the opinion that Walcott was in error in making the identification; for these reasons no attempt has been made to present a complete synonymy.

AUSTINVILLIA BILLINGSI Shaw, n. sp.
(Trilobite)
Pl. 73, figs. 1–4

Austinvillia n. sp SHAW, 1954, Geol. Soc. America Bull., vol. 65, p. 1038.

This is the only new species being described from the Lower Cambrian rocks covered by this paper.

The species is known from internal impressions of the head and tail and is immediately distinguishable from other Vermont ptychopariids by the extreme development of the border which is so long that the dorsal and marginal furrows merge in front of the glabella.

The cranidium is generally transverse. The glabella is truncato-conical, with faint traces of two pairs of glabellar furrows on some specimens, but most commonly smooth save for a well-incised occipital furrow, which sets off a short occipital ring. In small cranidia there is a low, small occipital node, but the large cranidia do not show it.

The fixed cheeks are about as wide as the glabella on a line through the midpoints of the eyes; they are slightly upsloping and are smooth except for the prominent ocular ridges, which lead to small palpebral lobes, lying about opposite the middle of the glabella. The posterior limbs are slightly wider than the occipital ring.

The border, the most striking feature of the head, is thickened but not inflated. In young cranidia, it is slightly less than half as long as the glabella sagittally and there is a slight brim between it and the front of the glabella, but in large heads it encroaches upon the brim and almost obliterates it, becoming about two-thirds as long as the glabella.

Thorax not known.

Three small ptychopariid pygidia have been found associated with the cranidia of *A. billingsi*, and as they are not assignable to the other species found at the type locality, they are placed here.

The axial lobe is narrow and bears three rings, plus the terminal segment and articulating half-ring. There are three interpleural grooves and each pleural segment is marked distally by a pleural furrow located posteriorly on the segment but running outward and forward. The rim is smooth and is set off only by a slight change in declivity, there being no marginal furrow.

This species is named for Dr. Marland P. Billings, who directed the thesis investigations that led to this report.

Holotype.—MCZ 5012.

Paratypes.—MCZ 5034a-o; MCZ 5036a-i; Univ. Wyoming IT-177a-d (cranidia); MCZ 5035a, b; Univ. Wyoming IT-178 (pygidia).

Type and only known locality.—M-NW-1, 0.50 mile N 64½° W of crossroads 266, two miles west of Georgia Center, Georgia

Township, Vermont. In leached ocherous residues of local dolomites in Parker slate, five to ten feet above the base of the formation.

Barrandia thompsoni (see **Olenellus thompsoni**)

Barrandia vermontana (see **Olenellus vermontanus**)

BATHYNOTUS HOLOPYGUS (Hall), 1859
(Trilobite)
Pl. 73, fig. 5

Peltura (Olenus) holopyga HALL, 1859, 12th Ann. Rept. New York State Cab. Nat. History, p. 61, fig. 3.
Paradoxides? quadrispinosus EMMONS, 1860, Manual of Geology, text-fig. 57, p. 80.
Bathynotus holopyga HALL, 1860, 13th Ann. Rept. New York State Cabinet Nat. History, pp. 117–119, text-fig.
Peltura (Olenus) holopyga BARRANDE, 1861, Soc. Geol. France Bull., 2d ser., vol. 18, pp. 278–280, pl. 5, figs. 9, 10.
Bathynotus holopyga HALL, in Hitchcock and others, 1862, Rept. Geology Vermont, vol. 1, pp. 371–372, pl. 13, fig. 3. ——, WALCOTT, 1886, U. S. Geol. Survey Bull. 30, pp. 191–193, pl. 31, figs. 1, 1a. ——, MILLER, 1889, North American Geology and Palaeontology, p. 532, fig. 970, Cincinnati, Ohio. ——, WALCOTT, 1891, U. S. Geol. Survey 10th Ann. Rept., pt. 1, p. 646, pl. 95, figs. 1, 1a.
Bathynotus holopygus RESSER & HOWELL, 1938, Geol. Soc. America Bull., vol. 49, p. 230, pl. 12, figs. 6, 7.

There is nothing to add to the figures given by Resser & Howell. A single pygidium has been found in the Kelly Quarry slates 150–160 feet above the base of the Parker slate. The specimen is small and probably immature so that reference to the species is only tentative. No other specimens are known or have been reported from any other locality.

Type locality.—Parker quarry, about 150 feet above the base of the Parker slate.

Holotype.—AMNH 233 (missing); Casts: Walker Mus. (Chicago) 13273 and USNM 67610 (fide Resser & Howell, 1938).

Bathyurus senectus (see **Bonnia senecta (?)**)

Genus BILLINGSASPIS Resser, 1935

Billingsaspis RESSER, 1935, Smithsonian Misc. Coll., vol. 93, no. 5, p. 16.
Ptychoparella RESSER, 1937, (part), Jour. Paleontology, vol. 11, pp. 43, 49.
Antagmus LOCHMAN, 1947 (part), Jour. Paleontology, vol. 21, p. 63.

Resser erected *Billingsaspis* on the species *Conocephalites vulcanus* Billings, 1861. In 1937, he assigned *C. vulcanus* to *Ptychoparella* Poulsen, 1927, and suppressed *Billingsaspis*. In reviewing these genera Lochman, in 1947, concluded that the species *C. vulcanus* was unidentifiable because of the fragmentary condition of the holotype.

Fortunately, a collection of several score topotypes of *C. vulcanus* and *C. adamsii* Billings, 1861, was available at the MCZ for study, and these specimens seem clearly to show that *C. vulcanus* and *C. adamsii* are synonymous, a suggestion made half a century ago by Matthew. Details of the species, which must be called "*adamsii*" by Matthew's choice, are given below.

Comments on Vermont ptychopariid trilobites.—In recent years there has been an increasing realization that the ptychopariid trilobites are in a confused state, and both Resser (1937) and Lochman (1947) have contributed to the attempt to bring order out of the chaos.

Inasmuch as there are several of the "generalized" ptychopariid types present in the Vermont section comments may not be amiss on *Antagmus, Billingsaspis, Perimetopus, Periomma* and *Ptychoparella;* all of these genera except the last have genotypes described from northwestern Vermont.

Lochman (1947) erected a set of generic and specific standards for the recognition of several Lower Cambrian genera, by which separations could be made and specimens identified. Rasetti (1951, pp. 201–202) has discussed these "diagnostic generic features" and has pointed out that the ratios between various cranidial parts, on which Lochman laid stress, is subject to far more variation within species than Lochman would permit between genera. This is amply borne out by the specimens studied here.

Further, Rasetti has observed that some of the criteria urged by Lochman seem of minor importance while at the same time she has omitted some that are useful, such as the effect of the facial suture pattern on the basic cranidial shape. Lochman's attempt to systematize generic criteria has been useful in pointing up some of the critical features to be examined in considering this difficult group, but it cannot avoid the

creation of a largely artificial grouping if applied vigorously.

In my own examination of the Vermont ptychopariids, I have come to regard the course of the facial suture as an important feature in addition to some of those set forth by Lochman. The general position of the eyes (central, in front of, or behind the middle of the cranidium) is also important, but not in so rigid a manner as proposed by Lochman. The other "diagnostic generic features" are sometimes useful, sometimes not.

In the Vermont specimens preservation is almost invariably in the form of internal molds, frequently flattened or otherwise distorted, but the genotypes come from the same rock, and with care much useful data can be obtained. The tendency to discard slate and sandstone specimens as useless is, I believe, unfortunate.

Two main types of trilobite cranidium can be recognized in the Vermont genera: (1) the transverse cranidium, outlined by facial sutures that run essentially straight forward from the eyes, being deflected more commonly outward than inward. *Billingsaspis* excellently illustrates this type. (2) the cranidium in which the facial sutures turn inward before the eyes and especially so in front of the point where they cross the anterior marginal furrow. This facial suture pattern produces a somewhat triangular cranidium, as is well shown by *Periomma* and *Antagmus*. These two facial suture patterns seem to me to be important because they imply fundamentally different ventral suture structures. In Type 1 there must be either a large rostrum or a long transverse submarginal furrow; in Type 2 neither can be present.

Of the Vermont species "*Conocephalites*" *adamsii* alone has the first type of facial suture. This is, therefore, the characteristic that distinguished this species from others in the area. *Billingsaspis*, of which *C. adamsii* must become the type, is distinguished by a wide cranidium, a short, truncato-conical glabella, posteriorly placed eyes and facial sutures that flare slightly before the eyes.

Antagmus, *Perimetopus*, *Periomma* and *Ptychoparella* all have the second type of facial suture, which trends inward before the eyes and may deflect even more sharply inward as it crosses the border. All these genera have narrow subtriangular cranidia. *Perimetopus* has a moderately long glabella that is rounded, or bullet-shaped in front. *Antagmus* and *Periomma* are very much alike, with small, truncate glabellae, unlike *Perimetopus*, but the former has a median, posteriorly-directed deflection of the marginal furrow, whereas *Periomma* has a normal border, with a median boss developed on the brim of *P. typicalis*.

BILLINGSASPIS ADAMSII (Billings), 1861
(Trilobite)
Pl. 73, figs. 6–12

Conocephalites adamsii BILLINGS, 1861, Geol. Survey Canada, Palaeozoic Fossils, vol. 1, pt. 1, pp. 12–13, fig. 15.
Conocephalites vulcanus BILLINGS, 1861, op. cit., p. 14, fig. 17.
Conocephalites Adamsii BILLINGS, 1862, Am. Jour. Sci., 2d ser., vol. 33, p. 104.
Conocephalites Vulcanus BILLINGS, 1862, loc. cit.
Conocephalites Adamsi BILLINGS, in Hitchcock and others, 1862, Rept. Geology Vermont, vol. 2, pp. 950–951, text-fig. 355.
Conocephalites vulcanus BILLINGS, in Hitchcock and others, 1862, op. cit., p. 952, text-fig. 357.
Conocephalites Adamsi LOGAN, 1863, Geology of Canada, fig. 294, p. 286.
Conocephalites Vulcanus LOGAN, 1863, Geology of Canada, fig. 296, ip. 286.
Ptychoparia adamsi WALCOTT, 1886, U. S. Geol. Survey Bull. 30, pp. 195–197, pl. 26, figs. 1, 1a, b only. Fig. 1c = *Ptychoparella teucer*.
[not] *Ptychoparia vulcanus* WALCOTT, 1886, op. cit., pp. 198–199, pl. 26, figs. 4, 4a. Fig. 4 = *Periomma typicalis* Resser, 1937. Fig. 4a = *Antagmus? simplex* Resser, 1937.
Crepicephalus vulcanus HILLER, 1889, North American Geology and Palaeontology, p. 540, Cincinnati, Ohio.
Ptychoparia adamsi WALCOTT, 1891 (part), U. S. Geol. Survey 10th Ann. Rept., pt. 1, p. 649, pl. 96, figs. 1, 1a–b only. Fig. 1c = *Ptychoparella teucer*.
[not] *Ptychoparia vulcanus* WALCOTT, 1891, op. cit., p. 653, pl. 96, figs. 4, 4a. Fig. 4 = *Periomma typicalis*. Fig. 4a = *Antagmus? simplex*.
Ptychoparia Adamsi MATTHEW, 1897, Royal Soc. Canada Proc. & Trans. for 1897, 2d ser., vol. 3, sec. 4, p. 199, pl. 4, fig. 9.
Suppresses *Conocephalites vulcanus*.
[not] *Ptychoparia Adamsi* MATTHEW, 1897, op. cit., p. 182, pl. 3, figs. 2 a, b.
[not] *Ptychoparia adamsi* WALCOTT, 1912, U. S. Geol. Survey Mon. 51, p. 189 [= *Periomma typicalis*].
[not] *Acrocephalites? vulcanus* WALCOTT, 1916, Smithsonian Misc. Coll. vol. 64, no. 3, p. 182, pl. 26, fig. 2 = *Periomma typicalis*.
Ptychoparia adamsi MCGERRIGLE, 1931, Vermont

State Geologist 17th Biennial Rept. for 1929–1930, p. 188.

Billingsaspis vulcanus RESSER, 1935, Smithsonian Misc. Coll., vol. 93, no. 5, p. 16.

Ptychoparella adamsi RESSER, 1936, Smithsonian Misc. Coll., vol. 95, no. 4, p. 14. ——, RESSER, 1937, Jour. Paleontology, vol. 11, p. 49, pl. 8, figs. 31–33.

Ptychoparella billingsi RESSER, 1937, op. cit., pp. 49–50, pl. 8, figs. 34–37.

Ptychoparella vulcana RESSER, 1937, op. cit., p. 50, pl. 8, figs. 38, 39.

Ptychoparella vermontensis RESSER, 1937, op. cit., p. 52, pl. 8, figs. 52, 53, 65.

Ptychoparella adamsi SCHUCHERT, 1937, Geol. Soc. America Bull., vol. 48, p. 1028.

Antagmus adamsi LOCHMAN, 1947, Jour. Paleontology, vol. 21, p. 65,

Ptychoparella? vermontensis LOCHMAN, 1947, op. cit., p. 66.

Antagmus adamsi KINDLE & TASCH, 1948, Canadian Field-Naturalist, vol. 62, p. 137, pl. 3, figs. 1, 2.

Billingsaspis adamsii SHAW, 1954, Geol. Soc. America Bull., vol. 65, pp. 1036, 1037, 1040, 1041, 1042, 1044.

This species has been referred to in many papers on Lower Cambrian faunas, but it has not been fully analyzed. Resser (1937) figured the types of *Conocephalites adamsii* and *C. vulcanus*, but illustration of the single specimens could not convey an impression of the variations to be found in the cranidium. The discovery of a large collection presumed topotypes of the two "species" has permitted their qualitative study. Unfortunately, there was not sufficient time to undertake the statistical study that should ultimately be made of the collection.

The crandium of *B. adamsii* shows three varieties of frontal limb, three developments of the eye-lines, and four variations of the glabellar shape. In addition, the glabellar furrows may be present or absent. It must be emphasized, however, that these types of cranidial structure are not distinct but intergrade insensibly with one another.

The frontal limb may have (1) a wholly concave brim, which grades into (2) a type in which there is a tumid, convex brim which may interrupt the marginal furrow mesially. The third and most common modification is a continuation of the second, in which a median boss is developed.

The eye-lines are rarely absent, more commonly faint, and most commonly well-developed.

The glabella shows variation from a relatively short to a relatively elongate shape, and it ranges from an evenly rounded transverse profile to a medially keeled profile.

To date six combinations of these cranidial features have been noted:

(1) Brim concave, eye lines faint, glabella large and keeled.

(2) Brim convex, eyelines faint, glabella large and keeled.

(3) Brim convex, eyelines strong, glabella small and keeled.

(4) Brim with boss, eyelines strong, glabella small and rounded.

(5) Brim with boss, eyelines faint, glabella large and keeled.

(6) Brim with boss, eyelines absent, glabella large and rounded.

But it must be re-emphasized that this selection of cranidial combinations does not represent six distinct varieties. Combination 1 grades in brim structure into combinations 2 and 3, which, in turn, grade into 4, 5 and 6; gradations in other features link other combinations. Thus, while some individuals may be separated quite readily from others, links intermediate in structure are found to fill the gaps. Combination 3 was the set of features to which Billings applied the name *Conocephalites vulcanus*. He emphasized the carinate glabella and the strong eyelines.

In view of the intergrading nature of the many cephala available it seems unwise to name each combination separately. Instead, there seems to be only one species, which is quite variable. To this species we must give the name *adamsii* as chosen by Matthew in 1897, since he was the first reviser (Art. 28 of the *Regles*). However, since *Conocephalites vulcanus* was chosen the type of *Billingsaspis*, and that species is now suppressed, *Conocephalites adamsii* must now become the type of *Billingsaspis*.

Two species, *Ptychoparella billingsi* and *P. vermontensis*, erected by Resser (1937), seem to be synonymous with *B. adamsii* and have been included in the synonymy given above. *P. billingsi* is a slate preservation and was suppressed by Lochman (1947), p. 65. *P. vermontensis* seems to represent Combination 4 listed above.

Holotype.—GSC 429 (fide Resser, 1937).

Type locality.—Locality B (Shaw, 1954, p. 1036), "about a mile east of Highgate Springs," probably 1000–1200 feet below the top of the Duham dolomite.

Known stratigraphic range.—From 1000–1200 feet below the top of the Dunham dolomite to 140 feet above the base of the Parker slate; also 50–100 feet above the base of the Monkton quartzite (Shaw, 1954, pp. 1036, 1037, 1040, 1041, 1042, 1044).

Billingsaspis vulcanus (see **Billingsaspis adamsii**)

BILLINGSASPIS WALCOTTI (Resser), 1937
(Trilobite)

Ptychoparella walcotti RESSER, 1937, Jour. Paleontology vol. 11, p. 52, pl. 8, figs. 47, 48.
Ptychoparella swantonensis RESSER, 1937, op. cit., p. 52, pl. 8, figs. 45, 46.
Ptychoparella walcotti LOCHMAN, 1947, Jour. Paleontology, vol. 21, p. 65. Suppresses *P. swantonensis*.
Billingsaspis walcotti Shaw, 1954, Geol. Soc. America Bull., vol. 65, p. 1042.

In *B. walcotti* the glabella is shorter and stouter than is typical of *B. adamsii*. There are no glabellar furrows and the glabellar profile is rounded. The brim is convex and without a median boss. The eyelines are strong. Eye position and sutures are as in *B. adamsii*.

Holotype.—USNM 65008.

Type and only known locality.—Hall Farm (USNM Loc. 25a) about 450 feet above the base of the Parker slate.

Billingsella festinata (see **Nisusia festinata**)
Billingsella orientalis (see **Wimanella? orientalis**)
Billingsella transversa (see **Nisusia transversa**)

BONNIA BUBARIS (Walcott), 1916,
emend. Rasetti, 1948
Pl. 73, figs. 13, 14

Corynexochus bubaris WALCOTT, 1916, Smithsonian Misc. Coll., vol. 64, no. 5, pp. 314–315, pl. 56, fig. 2 only.
Bonnia bubaris RESSER, 1936, Smithsonian Misc. Coll., vol. 95, no. 4, p. 10. ——, LOCHMAN, 1947, Jour. Paleontology, vol. 21, p. 69. ——, RASETTI, 1948, Jour. Paleontology, vol. 22, pp. 17–18, pl. 4, figs. 16–24.

This species has been recognized in the basal Parker at Locality SA-SC-14 (Shaw, 1954, pp. 1038–1039). It may be distinguished from *B. capito* by its longer, narrower, anteriorly flared glabella and by the slightly better-impressed glabellar furrows. Its is apparently synchronous with *B. capito*, although much rarer.

Holotype.—USNM 62734.

Type locality.—USNM Loc. 20; boulders at Bic, Quebec.

Only known locality in Vermont.—SA-SC-14, in the lower five feet of the Parker slate.

BONNIA CAPITO (Walcott), 1916
Pl. 73, figs. 15–25

Protypus senectus WALCOTT, 1886, not *Bathyurus senectus* Billings, 1861, U. S. Geol. Survey Bull. 30, p. 213, pl. 31, figs. 2, 2a–c.
Protypus senectus WALCOTT, 1891, U. S. Geol. Survey 10th Ann. Rept., pt. 1, p. 655, pl. 98, figs. 7, 7a–c.
Corynexochus capito WALCOTT, 1916, Smithsonian Misc. Coll., vol. 64, no. 5, pp. 315–316, pl. 57, figs. 2, 2a–e.
Bonnia capito (Walcott) RESSER, 1936, Smithsonian Misc. Coll., vol. 95, no. 4, p. 11.
Bonnia lata RESSER, 1936, loc. cit.
Bonnia swantonensis RESSER, 1936, loc. cit.
Bonnia vermontensis RESSER, 1936, op. cit., pp. 11–12.
Bonnia swantonensis RESSER, 1937, Jour. Paleontology, vol. 11, pp. 53–54, pl. 8, figs. 59, 62, 63. Suppresses *B. lata*.
Bonnia vermontensis RESSER, 1937, op. cit., p. 54, pl. 8, figs. 60, 61.
Bonnia tensa RESSER, 1938, Geol. Soc. America Special paper 15, p. 66, pl. 3, fig. 46.
Bonnia capito (Walcott). LOCHMAN, 1947, Jour. Paleontology, vol. 21, p. 69.
Bonnia swantonensis Resser. LOCHMAN, 1947, loc. cit.
Bonnia tensa Resser. LOCHMAN, 1947, loc. cit. ——, RASETTI, 1948, Jour. Paleontology, vol. 22, pp. 18–19, pl. 5, figs. 21–28.
Bonnia swantonensis KINDLE & TASCH, 1948, Canadian Field-Naturalist, vol. 62, p. 138, pl. 3, figs. 3, 4, 7–9.

An examination of a large suite of specimens of *Bonnia swantonensis* Resser, 1936, has led to the conclusion that that species is the same as *B. tensa* Resser, 1938, and that both are in turn the same as the older species *B. capito* (Walcott), 1916, with the differences among the so-called species actually being due to differences in preservation.

The bulk of the Vermont specimens of "*B. swantonensis*" come from leached, ocherous residues from weathered dolomites at the base of the Parker slate, with a few specimens found elsewhere. The specimens are preserved as internal impressions, but external impressions are left in the rock whence they come. Examination of the internal impressions shows that the Vermont form shows all of the peculiarities of *B. swantonensis*, but impressions of the external molds are identical with *B. tensa*, as that species was defined and elaborated by Rasetti in 1948. Shale preservations, in turn, show a tendency toward expansion of the

anterior of the glabella, due to flattening, as is characteristic of *B. capito* from the Kinzers slate of Pennsylvania. I suggest, therefore, that all subsequent names are actually synonymous with *Bonnia capito* and should be suppressed; these names include the two already mentioned, as well as *B. lata* Resser, 1936, and *B. vermontensis* Resser, 1936, both of which have previously been suppressed by Lochman (1947, p. 69).

This species has been admirably described by Rasetti under the name *B. tensa* and there seems little use in repeating his discussion here save to point out how preservation of the interior impression has rendered the Vermont specimens somewhat different in appearance from the better-preserved material from Quebec.

One difference that is immediately noticeable is the thinness of the rim in the Vermont specimens; this is due to a thickening of the shell here so that internal impressions show only part of the true rim; external molds show a rim identical with that shown in Rasetti's figures.

Similarly, there is a slight constriction of the anterior end of the glabella in the internal impressions while the outer surface shows no trace of it. This again is due to a thickened spot on the shell. The rear of the cranidium shows no essential differences between the inside and the outside.

The pygidia from Vermont show a more prominent development of all furrows but this is a common occurrence when the inside and outside of this shield are compared.

One point which has emerged from the study of the Vermont *Bonnia* is that spinosity of the pygidium is variable within the species. The common pygidial type is that shown by Rasetti, with a very small pair of spines at the anterior angles. However, in a few specimens these spines have developed quite prominently, and in rare specimens a three-spined condition appears, similar to that illustrated by Walcott (1916, pl. 56, figs. 3d-c) in *Bonnia bubaris*. There seems little reason for regarding these pygidial variations as of specific value, for they give the impression of being minor and uncommon mutants within the population. Another scarce variation is the presence of a pronounced indentation in the posterior edge of the pygidium, as compared with the normal pygidia which have only the slightest trace of a deflection in the posterior margin.

Holotype.—USNM 62746–62747 (fide Resser, 1937).

EXPLANATION OF PLATE 73

All specimens figured are natural internal molds

FIGS. *1–4—Austinvillia billingsi* Shaw, n. sp. *1*, Dorsal stereophotos of holotype cranidium (MCZ 5012), ×2. *2, 3*, Anterior and lateral views of holotype, ×2. *4*, Paratype pygidium (MCZ 5035a), ×7. Locality M-NW-1, basal 10 feet of Parker. (p. 777)

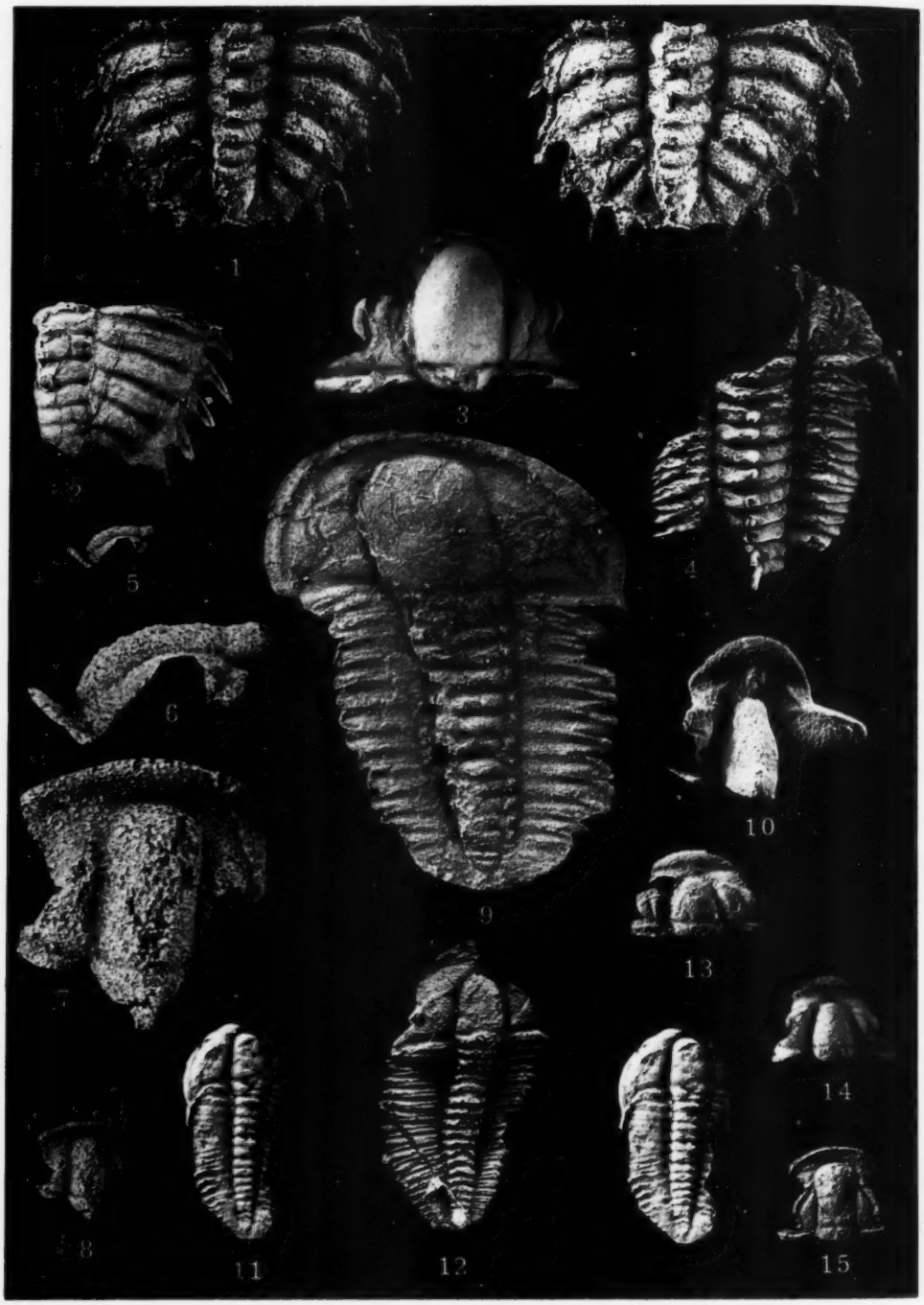
5—Bathynotus holopygus (Hall), 1859?. Pygidium tentatively assigned to species (MCZ 5040), ×5½. Locality SA-C-1 (Kelly quarry slates) about 155 feet above base of Parker. (p. 778)

6–12—Billingsaspis adamsii (Billings), 1861. *6, 7*, Cranidium with median boss and eyelines and without glabellar keel, ×2½ and ×6. *8*, Cranidium with convex brim, faint eyelines and no glabellar keel (MCZ 3253), ×5½. *9, 10*, Cranidium with convex brim, eyelines and keeled glabella (the combination of features called *Conocephalites vulcanus* Billings, 1861), ×2½ and ×5½. *11, 12*, Cranidium with median boss and eyelines and without glabellar keel (MCZ 2932), ×2½ and ×5½. All specimens from a collection in MCZ made by J. B. Perry, probably at Locality B, 600–1200 feet below the top of the Dunham dolomite. (p. 779)

13, 14—Bonnia bubaris (Walcott), 1916. *13*, Half cranidium (MCZ 5039b). ×2. *14*, Lateral view of second cranidium (MCZ 5039a), ×2. From Locality SA-SC-14, lower five feet of Parker. (p. 781)

15–25—Bonnia capito (Walcott), 1916. *15–17*, Dorsal, lateral and anterior views of cranidium (MCZ 5013b), ×2. *18*, Hypostoma assigned to species (MCZ 5046a), ×7. *19*, Immature pygidium (MCZ 5045), ×6. *20, 21*, Dorsal and lateral views of normal pygidium (MCZ 5013c), ×2. *22*, Pygidium with unusual bilobate margin (MCZ 5013a), ×2. *23*, Pygidium with median indentation in rear margin (MCZ 5044), ×2. *24, 25*, Small cranidium in slate (MCZ 5038), ×2½ and ×6½. *15–23* from Locality M-NW-1 in basal 10 feet of Parker. *24, 25* from Locality M-NC-2U, about 140 feet above base of the Parker. (p. 781)

Shaw, The Lower Cambrian fauna, Vermont



Shaw, The Lower Cambrian fauna, Vermont

Type locality.—USNM Loc. 48b, Kinzers slate, York, Pennsylvania (fide Resser, 1937).

Stratigraphic range in Vermont.—Lower 150 feet of the Parker slate and in the lower Monkton quartzite. Resser (1937, pp. 53, 54) suggested that the types of *B. swantonensis* and *B. vermontensis* came from USNM Loc. 28, but the stratigraphic and geographic positions of this locality cannot now be determined (Shaw, 1954, pp. 1038, 1039(?), 1040, 1041(?), 1044).

Bonnia lata (see **Bonnia capito**)

BONNIA SENECTA (Billings), 1861 (?)
(Trilobite)

Bathyurus senectus BILLINGS, 1861, Geol. Survey Canada, Palaeozoic Fossils, vol. 1, p. 15, figs. 19, 20.
Protypus senectus WALCOTT, 1912, U. S. Geol. Survey Mon. 51, vol. 1, p. 188. Listed from USNM Loc. 25a.
Bonnia senecta(?) SHAW, 1954, Geol. Soc. America Bull., vol. 65, p. 1042.

Walcott identified this species in Vermont until 1916, when he referred Vermont specimens to *Bonnia capito.* In 1912 he listed *B. senecta* from the Hall Farm (USNM Loc. 252), and inasmuch as he did not specifically refer this citation to *B. capito* it remains in the literature, but probably the species referred to is not *B. senecta* but *B. capito.*

Bonnia swantonensis (see **Bonnia capito**)
Bonnia tensa (see **Bonnia capito**)
Bonnia vermontensis (see **Bonnia capito**)

BONNIELLA DESIDERATA (Walcott), 1891
(Trilobite)

Olenoides (Dorypyge) desiderata WALCOTT, 1891, U. S. Geol. Survey 10th Ann. Rept., pt. 1, pp. 644–645, text-fig. 67.
Dorypyge desiderata MATTHEW, 1897, Royal Soc. Canada Trans., 2d ser., vol. 3, sec. 4, p. 187.
Olenoides desiderata WALCOTT, 1912, U. S. Geol. Survey Mon. 51, vol. 1, p. 188.
Bonniella desiderata RESSER, 1937, Smithsonian Misc. Coll., vol. 95, no. 22, p. 5. ——, RESSER, 1938, Geol. Soc. Amercia Spec. Paper 15, 66, pl. 2, figs. 6–8. ——, R. & E. RICHTER, 1941, Senckenberg. naturf. Gesell. Abh. 455, p. 36.

The figures given by Resser in 1938 and the discussion by Walcott in 1891 are adequate and easily accessible so no additions need be made here.

Syntypes.—USNM 18452, 18453 (Resser, 1938, p. 66).

EXPLANATION OF PLATE 74

All specimens figured are natural internal molds except figs. 2, 9, 11 and 12 which are artificial casts

FIGS. *1–4*—*Kootenia marcoui* (Whitfield), 1884. *1.* Stereophotos of pygidium (MCZ 4996) from Locality M-NW-1, basal 10 feet of Parker, ×1-2/3. *2,* Rubber squeeze (U. Wyo. IT-139) of holotype pygidium (AMNH 236) from Parker quarry (USNM Loc. 319m), ×1, *3,* Best cranidium from Locality SA-C-1 (Kelly quarry dolomites), about 160–165 feet above base of Parker (MCZ 5003) ×1. *4,* Rubber squeeze (U. Wyo. IT-140) of articulated thorax and fragmentary cephalon (MCZ 4995) from Kelly quarry slates, about 150–160 feet above base of Parker, ×1. (p. 786)

5–8—*Zacanthopsis* sp. indet. Lateral and dorsal views of cranidium (MCZ 5011), ×2 and ×5½. (p. 803)

9—*Protypus hitchcocki* (Whitfield.) 1884. Plaster cast (USNM 15424) of missing holotype (AMNH 232) from Parker quarry (USNM Loc. 319 m), ×2. Negative supplied by Dr. G. A. Cooper. (p. 799)

10—*Periomma typicalis* Resser, 1937. Laterally compressed cranidium (MCZ 5009), ×2½. Locality M-NC-2U, about 140 feet above base of Parker. (p. 797)

11–14—*Ptychoparella teucer* (Billings), 1861. *11,* Stereophotos of a guttapercha cast of the holotype (MCZ 2920) of *Ptychoparella georgiensis* Resser, 1937, from Parker quarry (USNM Loc. 319m). ×1½. *12,* Rubber squeeze (U. Wyo IT-141) of external mold of entire specimen (MCZ 4993), ×2. *13,* Cranidium with pygidium of *Pagetides parkeri* exposed through cheek (MCZ 5025h), ×2. *14,* Normal cranidium (MCZ 5025g), ×2½. Figures 12–14 from Locality SA-C-1 (Kelly quarry slates) 150–160 feet above base of Parker. (p. 800)

15—*Prozacanthoides* sp. indet. Unique flattened cranidium (MCZ 4991) from Locality SA-C-1 (see above), ×2. Diagonal grooves on rear half of glabella are pressure cracks and not glabellar furrows. (p. 799)

Type and only known locality.—1½ miles east-southeast of Highgate Springs (Walcott, 1891, p. 645), presumably in the Dunham. Resser (1938, p. 66) gives USNM Loc. 26, but the confusion regarding this locality has already been discussed (Shaw, 1954, p. 1036).

BOTSFORDIA CAELATA (Hall), 1847 (Brachiopod)

Orbicula caelata HALL, 1847, Paleontology of New York, vol. 1, p. 290, pl. 79, figs. 9a–c.
Lingulella caelata HALL & CLARKE, 1892, 11th Ann. Rept. State Geologist New York for 1891, pl. 3, figs. 1–4. ——, WALCOTT, 1886, U. S. Geol. Survey Bull. 30, pp. 95–97, pl. 7, figs. 1, 1a–d. ——, MILLER, 1889, North American Geology and Palaeontology, p. 352, Cincinnati, Ohio.
Botsfordia caelata WALCOTT, 1912, U. S. Geol. Survey Mon. 51, pp. 251, 603–605, pl. 59, figs. 1, 1a–g, 3, 3a–b.

This species has been listed from a collection made about 600 feet below the top of the Dunham (USNM Loc. 319j), but otherwise no data on it are available, and for the present at least its existence in Vermont may be regarded as unproved.

Holotype.—American Museum of Natural History 205 (missing).

Type locality.—"Hudson—river shales, near Troy," New York.

Buthotrephis? asteroides (see **Dactyloidites asteroides**)
Bythotrephis asteroides (see **Dactyloidites asteroides**)
Calodiscus parkeri (see **Pagetides parkeri**)
Camarella antiquata (see **Swantonia antiquata**)
Camerella antiquata (see **Swantonia antiquata**)
Climacograptus?? emmonsi (see **Anomalocaris? emmonsi**)
Conocephalites Adamsii (see **Billingsaspis adamsii**)
Conocephalites arenosus (see **Perimetopus arenosus**)
Conocephalites teucer (see **Ptychoparella teucer**)
Conocephalites vulcanus (see **Billingsaspis adamsii**)
Conocoryphe trilineata (see **Atops trilineata**)
Corynexochus bubaris (see **Bonnia bubaris**)
Corynexochus captio (see **Bonnia capito**)
Crassifimbra? georgiensis (see **Ptychoparella teucer**)
Crepicephalus vulcanus (see **Billingsaspis adamsii**)

DACTYLOIDITES ASTEROIDES (Fitch), 1850 (Alga?)

Buthotrephis? asteroides FITCH, 1850, New York State Agric. Soc. Trans. for 1849, vol. 9, p. 863.
Dactyloidites bulbosus HALL, 1886, Regents State Mus. Nat. History New York 39th Ann. Rept. for 1885, p. 160, pl. 11, figs. 1, 2.
Bythotrephis asteroides MILLER, 1889, North American Geology and Palaeontology, p. 109, Cincinnati, Ohio. (variant spelling)
Dactyloidites asteroides WALCOTT, 1891, U. S. Geol. Survey 10th Ann. Rept., pt. 1, pp. 605–606, fig. 61. ——, RUEDEMANN, 1934, Geol. Soc. America Mem. 2, pp. 28–29, pls. 4, 5.

Ruedemann has adequately described this species.

Holotype.—NYSM 3300/1 (Clarke & Ruedemann, 1903, p. 44).

Only known Vermont locality.—Top of slates in Kelly quarry, about 160 feet above base of Parker slate, where it is found in great profusion.

Dactyloidites bulbosus (see **Dactyloidites asteroides**)

DACTYLOIDITES EDSONI Ruedemann, 1934 (Alga?)

Dactyloidites edsoni RUEDEMANN, 1934, Geol. Soc. America Mem. 2, p. 30, ftn. 54, pl. 6, figs. 1, 2. ——, RESSER & HOWELL, 1938, Geol. Soc. America Bull., vol. 49, p. 210.

This species was described by Ruedemann as coming from the "late Middle Cambrian. Franklin County, Vermont", but as Resser and Howell have pointed out the types are from the Kelly quarry slate zone (SA-C-1), about 160 feet above the base of the Parker slate. The species is not known elsewhere.

D. edsoni has thicker rays than *D. asteroides*, but inasmuch as they are found together, the possibility should be considered that *D. edsoni* is only a variant of *D. asteroides*.

Holotype.—Princeton University 40347a (fide Resser & Howell 1938).

DICTYONEMA SCHUCHERTI Ruedemann, 1933 (Graptolite-Late Cambrian)

Dictyonema schucherti RUEDEMANN, 1933, Public Mus. City of Milwaukee Bull., vol. 12, no. 3, p. 321, pl. 54, figs. 1, 2.

Ruedemann described this species as coming from the "Lower Cambrian, top of Colchester [*i.e.*, Parker] formation: about one mile northwest of Highgate Center, Vermont." On page 331 of the same work he gave the age as Middle Cambrian. This graptolite belongs correctly in the Dresbachian Hungerford slate (probably *Cedaria* zone) and is not a member of the Lower Cambrian fauna.

Dikellocephalus? marcoui (see **Kootenia marcoui**)

Diplograptus simplex (see **Emmonsaspis cambrensis**)

Elliptocephala thompsoni (see **Olenellus thompsoni**)

EMMONSASPIS CAMBRENSIS (Walcott), 1891 (Affinities unknown)

Diplograptus? simplex WALCOTT, 1886 (not *Fucoides simplex* Emmons, 1844), U. S. Geol. Survey Bull. 30, pp. 92–93, pl. 11, figs. 4, 4a.
Phyllograptus? simplex WALCOTT, 1889, Am. Jour. Sci., 3d ser., vol. 37, p. 388.
Phyllograptus?? cambrensis WALCOTT, 1891, U. S. Geol. Survey 10th Ann. Rept., pt. 1, pp. 604–605, pl. 59, figs. 3, 3a.
Emmonsaspis cambriensis RESSER & HOWELL, 1938, Geol. Soc. America Bull., vol. 49, p. 233, pl. 9, figs. 1–4. (variant spelling).

The history of the name of this fossil was discussed by Walcott in 1891, and excellent illustrations have been presented by Resser & Howell.

Holotype.—USNM 15314.

Type and only known locality.—Parker quarry, about 150 feet above the base of the Parker slate.

EOCYSTITES sp. indet (Cystid)

Eocystites? sp.? WALCOTT, 1886, U. S. Geol. Survey Bull. 30, p. 46.
Eocystites WALCOTT, 1891, U. S. Geol. Survey 10th Ann. Rept., pt. 1, p. 607.

Walcott twice mentioned the presence of cystid plates in the Parker but figured no specimens. None of the Lower Cambrian specimens is well enough preserved to warrant illustration. Better-preserved specimens are present in the Middle Cambrian beds.

Stratigraphic range. —140 feet above base of Parker (M-NC-2U) to *Albertella* zone slates at Donaldson quarry 190 feet above middle Parker dolomite.

Goniodiscus parkeri (see **Pagetides parkeri**)

HUENELLA BILLINGSI (Walcott), 1905 (Brachiopod—Late Cambrian)

Syntrophia billingsi WALCOTT, 1905, U. S. Nat. Mus. Proc., vol. 28, no. 1395, pp. 291–292.
Huenella billingsi WALCOTT, 1912, U. S. Geol. Survey Mon. 51, pp. 189, 806, pl. 102, figs. 5, 5a–c. ——, SCHUCHERT & COOPER, 1932, Peabody Mus. Nat. History Yale Univ. Mem., vol. 4, pt. 1, p. 159, ——, SHAW, 1952, Jour. Paleontology, vol. 26, pp. 482–483.

In the original description of this species, Walcott correctly dated the rocks as Upper Cambrian, but it was later reported by Walcott (1912, p. 189) from "Middle? Cambrian" limestones (USNM Loc. 28a) where it was said to be associated with the Lower Cambrian species *Lingulella franklinensis* and *Ptychoparia adamsi.* As is pointed out in the discussion of the former species on a later page, USNM Loc. 28a is certainly part of the Upper Cambrian Rockledge conglomerate.

HYOLITHELLUS MICANS (Billings), 1871 (Mollusk?)

Hyolithes? micans BILLINGS, 1871, Canadian Naturalist, n. ser., vol. 6, pp. 215–216, figs. 3a, b.
Hyolithellus micans BILLINGS, 1871, op. cit., p. 240 (Publication date given as December, 1871). ——, WALCOTT, 1886, U. S. Geol. Survey Bull. 30, pp. 142–143, pl. 14, figs. 2, 2a–c. ——, WALCOTT, 1891, U. S. Geol. Survey 10th Ann. Rept., pt. 1, p. 624, pl. 79, figs. 1, 1a–c. ——, WALCOTT, 1921, U. S. Geol. Survey Mon. 51, vol. 1, p. 251.

This species has been cited from the "Georgia Formation" (=Parker slate) (Walcott, 1886) and from USNM Locality 319j, about 600 feet below the top of the Dunham (Walcott, 1912), but its presence has not been confirmed in my own collections or by reports of others. No Vermont specimen has yet been illustrated.

The wide distribution of the species makes it not improbable that it could have lived in northwestern Vermont, but on the basis of available information *H. micans* cannot be regarded as a proved member of either the Dunham or Parker faunas.

Cotype.—GSC 411h.

Type locality.—Bic and St. Simon, Quebec, and Troy, New York (all were listed by Billings).

HYOLITHELLUS? sp. indet.

One specimen of what may be an *Hyolithellus* has been found at the base of the transition zone between the Gilman quartzite and the overlying Dunham dolomite at Locality EF-WC-1 which lies at the 320-foot contour on the crest of the ridge 0.80 mile S81°W of Bench Mark 345 at Sheldon Springs, in the Enosburg Falls quadrangle.

Specimen in MCZ (unnumbered).

HYOLITHES AMERICANUS Billings, 1871 (Mollusk)

Hyolithes americanus BILLINGS, 1871, Canadian Naturalist, new ser., vol. 6, p. 215, figs. 2a, b. ——, WALCOTT, 1886, U. S. Geol. Survey Bull. 30, pp. 132–133, pl. 13, figs. 6, 6a–f. ——, MILLER, 1889, North American Geology and Paleontology, p. 391, Cincinnati, Ohio. ——, WALCOTT, 1891, U. S. Geol. Survey 10th Ann. Rept., pt. 1, p. 620, pl. 75, figs. 2, 2a–f, text-fig. 64. ——, WALCOTT, 1912, U. S. Geol. Survey Mon. 51, vol. 1, p. 251, ——, SCHUCHERT, 1937, Geol. Soc. America Bull., vol. 48, p. 1034. ——, SHIMER & SHROCK, 1944, Index Fossils of North America, p. 525, pl. 215, figs. 1–6. ——, SINCLAIR, 1946, Jour. Paleontology, vol. 20, p. 73.

An hyolithid with the outline of *H. americanus* is common throughout the Parker and is especially abundant in Middle Cambrian beds at Locality SA-EC-1 but inasmuch as specimens are invariably flattened positive identification is impossible.

Holotype.—GSC 396g.

Paratypes.—GSC 396a–f, GSC 397a–c.

Type locality.—Bic and St. Simon, Quebec, and Troy, New York, all listed by Billings.

Stratigraphic range.—The unconfirmed report of Walcott (1912) places the species at USNM Loc. 319j, about 600 feet below the top of the Dunham, and many specimens are present in the limestone at Locality SA-NE-11, at the top of Dunham. Specimens questionably identified with *H. americanus* range in the Parker as high as Locality SA-EC-1, 190 feet bove the middle dolomite (*Albertella* zone) (Shaw, 1954, pp. 1036, 1037, 1042, 1043).

HYOLITHES COMMUNIS Billings, 1871 (Mollusk)

Hyolithes communis BILLINGS, 1871, Canadian Naturalist, new ser., vol. 6, pp. 214–215, figs. 1a, b. ——, WALCOTT, 1886, U. S. Geol. Survey Bull. 30, pp. 136–137, pl. 14, figs. 3, 3a–e. ——, MILLER, 1889, North American Geology and Palaeontology, p. 391, Cincinnati, Ohio. ——, WALCOTT, 1891, U. S. Geol. Survey 10th Ann. Rept., pt. 1, p. 620, pl. 77, figs. 3, 3a–g. text-fig. 65. ——, WALCOTT, 1912, U. S. Geol. Survey Mon. 51, p. 251. ——, SHIMER & SHROCK, 1944, Index Fossils of North America, p. 525, pl. 215, figs. 34–41, John Wiley, New York. ——, SINCLAIR, 1946, Jour. Paleontology, vol. 20, p. 74 (listed.)

Holotype.—missing (W. A. Bell, letter, Sept. 9, 1952).

Type locality.—Bic and St. Simon, Quebec.

Range.—This species is known only from the unconfirmed report of its presence at USNM Loc. 319j about 600 feet below the top of the Dunham (Walcott, 1912).

HYOLITHES sp. indet. (Mollusk)

Unidentifiable specimens of *Hyolithes* have been found at the base of the transition zone between the Gilman quartzite and the Dunham dolomite at Locality EF-WC-1, at about 500 feet below the top of the Duham at Locality SA-NC-1, and at USNM Loc. 26, somewhere in the Dunham (Shaw, 1954, pp. 1034. 1036, 1037).

Iphidea bella (see **Paterina bella** and **P. labradorica swantonensis**)

Iphidea labroadorica swantonensis or *I. labradorica* var. *swantonensis* (see **Paterina labradorica swantonensis**)

Iphidella labradorica swantonensis (see **Paterina labradorica swantonensis**)

KOOTENIA MARCOUI (Whitfield), 1884 (Trilobite)
Pl. 74, fig. 1–4

Dikellocephalus? marcoui WHITFIELD, 1884, Am. Mus. Nat. History Bull., vol. 1, p. 150, pl. 14. fig. 7.

Olenoides? marcoui WALCOTT, 1886, U. S. Geol. Survey Bull. 30, pp. 186–187, pl. 26, figs. 5, 5a–b.

Dicellocephalus marcoui MILLER, 1889, North American Geology and Palaeontology, p. 544, Cincinnati, Ohio.

Olenoides marcoui LESLEY, 1889, Geol. Survey Pennsylvania Rept. P-4, vol. 2, p. 493. ——, WALCOTT, 1891, U. S. Geol. Survey 10th Ann. Rept., pt., p. 642, pl. 94, figs. 2, 2a–b.

Kootenia marcoui RESSER, 1937, Smithsonian Misc. Coll., vol. 94, no. 22, p. 16.

[probably] *Kootenia* cf. *K. marcoui* Rasetti, 1948, Jour. Paleontology, vol. 22, p. 14, pl. 3, fig. 7.

A well preserved pygidium from nearly the same level as the holotype permits us to enlarge on the description of that part. In addition, several cranidia better preserved than that previously figured have been recovered.

Pygidial pleura fused as is typical of the genus. Fourteen marginal spines which is the number that Rasetti (1948B, p. 332) has noted as being typical of most Lower Cambrian species. Axial lobe narrow; in largest specimen it bears six rings plus the articulating half-ring and terminal segment; apparently the same in the holotype. Axial rings lie opposite the pleural grooves. There are five pleural segments. The first four axial rings of internal impressions bear low nodes that are the site of axial spines. Measurements were made on five pygidia of the following dimensions: Maximum pygidial width at anterior end of marginal furrow; maximum width of axial lobe at anterior end; length of axial lobe including articulating half-ring; length of pygidium in sagittal plane, number of axial segments excluding half-ring and terminal segment; and number of pleural segments. These data, in millimeters, 24.5, 6.2, 17.0, 18.8, 6, 5 (MCZ 4996 from Loc. M-NW-1); *24.8*, 8.0 ,13.5, 15.0, 6, 5 (Univ. Wyoming IT-269 from dolomite above Kelly Quarry, Loc. SA-C-1); 19.0, 5.9, 12.0?, 12.8?, —, 5 (MCZ 4997, same locality as IT-269); 18.0, 5.0, 12.3, —, —, 5 (MCZ 4998, same locality at IT-269); *16.2*, 5.8, 11.4, 12.5, —, 5 (MCZ 4999, same locality as IT-269). Italicized figures show measurements made on one side of the pygidium and doubled.

The cranidium is not specifically distinctive. The glabella is long, rounded in front and gently tapered. Faint traces of as many as three glabellar furrows are visible on rare specimens, but most glabellae are smooth. The occipital furrow is straight and the occipital ring may have borne a node or spine. The fixed cheeks are horizontal. There are eyelines and palpebral furrows, The palpebral lobe is long and is centered about opposite the midpoint of the glabella (including the occipital ring). There is a narrow but prominent, upturned rim set off by a deep marginal furrow. The rim narrows only slightly in front of the glabella.

A unique specimen (MCZ 4995) of an articulated thorax of this species (Pl. 74, fig. 4) was found in the Kelly quarry slates (SA-C-1). The rear of the cephalon is retained and behind that there are ten segments, but it is not apparent whether the last two are part of the thorax or the pygidium. Each of the ten segments bears a spine, directed backward at about 45°. The pleural furrows are almost straight, and the fulcrum lies at about the midpoint of the pleural lobe. The right free cheek is in place in this specimen and shows the genal spine diverging at an angle of 32° from the axis of the body, an angle that may have been increased by flattening. The eyes appear to have been simple.

The holotype pygidium from the American Museum of Natural History was kindly loaned for this study through the courtesy of Dr. Otto Haas, and it is figured for the first time photographically. Although fragmentary, enough of it remains to make identification of the species certain. The holotype is the only specimen seen that gives the impression of the outer surface and the axial spines of the pygidium; unfortunately, the spines could not be cast successfully.

Holotype.—AMNH 236.

Type locality.—Slates of Parker quarry (USNM Loc. 319g), about 150 feet above the base of the Parker slate.

Stratigraphic range.—Lower Parker slate, from 5–10 feet above the base to the Parker-Kelly zone 160–165 feet above the base. Unconfirmed report of the species at USNM Loc. 25, 170–210 feet above base. Reports of the species higher in the formation are probably incorrect and may refer to *K. boucheri* (Shaw, 1954, pp. 1034, 1040, 1041).

KUTORGINA CINGULATA (Billings), 1861
(Brachiopod)
Pl. 76, figs. 1, 2

Obolella cingulata BILLINGS, 1861, Canada Geol. Survey Palaeozoic Fossils, vol. 1, pt. 1, p. 8, figs. 7–9. Proposes generic name *Kotorgina* in footnote. Spelling corrected to *Kutorgina* in 1865 edition. ——, BILLINGS, 1862, Am. Jour. Sci., 2d ser., vol. 33, pp. 102, 104. Also notes generic name *Kotorgina* [sic]. ——, BILLINGS, in Hitchcock and others, 1862, Rept. Geology Vermont, vol. 2, p. 948, figs. 347–349. ——, OGAN, 1863, Geology of Canada, figs. 287a–c, p. 284 (no text).

Kutorgina cingulata WALCOTT, 1886, U. S. Geol. Survey Bull. 30, pp. 102–104, pl. 9, figs. 1,

1a–h. ——, MILLER, 1889, North American Geology and Palaeontology, p. 347, Cincinnati, Ohio. ——, WALCOTT, 1891, U. S. Geol. Survey 10th Ann. Rept. pt. 1, p. 609, pl. 69, figs. 1, 1a–h. ——, HALL & CLARKE, 1892, Palaeontology of New York, vol. 8, pt. 1, pp. 90–94, pl. 4, figs. 10–17, ——, SCHUCHERT, 1897, U. S. Geol. Survey Bull. 87, p. 286. ——, WALCOTT, 1905, U. S. Nat. Mus. Proc., vol. 28, no. 1395, pp. 308–309. ——, WALCOTT, 1912, U. S. Geol. Survey Mon. 51, pp. 580–582, text figs. 3, 50a–c, pl. 5, figs. 1, 1a–s. (Gives full synonymy to 1912). ——, SHIMER & SHROCK, 1944, *Index fossils of North America*, p. 293, pl. 110, figs. 1–3. ——, KINDLE & TASCH, Canadian Field-Naturalist, vol. 62, p. 138 (not figured).

An examination of Part I of "Palaeozoic Fossils" shows that Billings originally spelled the generic name of this brachiopod as *Kotorgina*. However, in 1865 he emended the spelling to the commonly accepted version *Kutorgina*, which has been used exclusively since that time. There seems to be little value in insisting upon a returning to *Kotorgina*, even though it may have some technical claim to recognition, for the name has not been used and is based upon an erroneous spelling of Kutorga's name.

Walcott (1912) has fully described *K. cingulata*, which is widely distributed through the Lower Cambrian in Vermont. Clark (1936, p. 146) has reported it from as low as the Gilman quartzite and it is present in the overlying Dunham dolomite, but most specimens of *K. cingulata* appear to have come from the so-called "Hall Farm" locality about 450 feet above the base of the Parker slate. Recently, *K. cingulata* has also been reported from the Monkton formation by Kindle and Tasch (1948, p. 138).

See additional comments under the species *Rustella edsoni*.

Holotype.—missing (W. A. Bell, letter, Sept. 9, 1952).

Type locality.—Anse au Loup, on the north shore of the Straits of Belle Isle. In limestone of the Potsdam group. (Billings, 1861, p. 9).

Stratigraphic range.—Gilman quartzite (position in formation uncertain) to "Hall Farm" (USNM Loc 25a) about 450 feet above base of Lower Parker slate. Also present 50–100 feet above base of Monkton quartzite (Shaw, 1954, pp. 1038, 1039, 1040, 1042, 1044).

Kutorgina labradorica var. *swantonensis*
(see **Paterina labradorica swantonensis**)

LEPTOMITUS ZITTELI Walcott, 1886
(Sponge)

Leptomitus zitteli WALCOTT, 1886, U. S. Geol. Survey Bull. 30, p. 89, pl. 2, figs. 2, 2a. ——, MILLER, 1889, North American Geology and Palaeontology, p. 160, Cincinnati, Ohio. ——, WALCOTT, 1891, U. S. Geol. Survey 10th Ann. Rept., pt. 1, p. 597, pl. 4, figs. 1, 1a. ——, RESSER & HOWELL, 1938, Geol. Soc. America Bull., vol. 49, p. 211, pl. 1, figs. 12–14.

This sponge has been well illustrated by Resser and Howell. It has been noticed in moderate local abundance at the Parker quarry level and for a short distance above, but it is not found away from the immediate vicinity of Parker Cobble.

Holotype.—USNM 15308.

Type locality.—Parker quarry, about 150 feet above the base of the Parker slate (USNM Loc. 319m; not USNM Loc. 25, as reported by Resser and Howell. Omitted from list in Shaw, 1954, p. 1040).

Known range.—150 to 200 feet above base of Parker slate.

Lingulella caelata (see **Botsfordia caelata**)

LINGULELLA FRANKLINENSIS (Walcott),
1912 (Brachiopod—Late? Cambrian)

Obolus (*Lingulella*) *franklinensis* WALCOTT, 1898, U. S. Nat. Mus. Proc., vol. 21, no. 1152, pp. 404–405.

Lingulella franklinensis WALCOTT, 1912, U. S. Geol. Survey Mon. 51, pp. 189, 217, 501–502, pl. 26, figs. 3, 3a–b.

This species has been reported from two localities in northwestern Vermont. The first is Locality 28a, described by Walcott (1912 p. 189) as:

Middle? Cambrian: "St. Albans formation," in limestone lentile about 1 mile (1.6 km) east of Parker's quarry, near Georgia, Franklin County, Vt.

Associated fossils are listed as *Huenella billingsi* (Walcott), 1905, and *Ptychoparia adamsi* (Billings), 1861. Locality 28a is now known to be part of the Dresbachian Rockledge conglomerate and not of Lower Cambrian age. Inasmuch as Walcott identified "*P. adamsi*" from nearly every Cambrian zone in northwestern Vermont, his citation cannot be regarded as arguing strongly for a Lower Cambrian age for *L. franklinensis*. Schuchert (1937, p. 1060) noted that this bed was Upper Cambrian, but still spoke of *L. franklinensis* as a Lower Cambrian species.

Walcott (1912, p. 217) also reported *L. franklinensis* from Locality 87:

Lower Cambrian: Limestone 1 mile (1.6 km) south-southwest of Highgate Falls, Franklin County, Vermont.

where the associated species are *Micromitra* (*Paterina*) *labradorica swantonensis* and *Obolus?* sp. undet. This locality seems, by the directions given, to belong in either the Rockledge conglomerate or the Hungerford slate, probably the former, for limestone is uncommon in the Hungerford,. Both of these formations are Dresbachian (Shaw, 1952, p. 458).

Thus, it seems that *Lingulella franklinensis* must be stricken from the list of Lower Cambrian fossils and put in the Upper Cambrian.

Holotype.—USNM 27318.

LINGULELLA GRANVILLENSIS Walcott, 1887 (Brachiopod)

Lingulella granvillensis WALCOTT, 1887, Am. Jour. Sci., 3d ser., vol. 34, pp. 188–189, pl. 1, figs. 15, 15a–c. ——, WALCOTT, 1891, U. S. Geol. Survey 10th Ann. Rept., pt. 1, pp. 607–608, pl. 67, figs. 4, 4a–d. ——, WALCOTT, 1912, U. S. Geol. Survey Mon. 51, pp. 188, 504–505, pl. 22, figs. 1, 1a–d.

Walcott reported this species from the Hall Farm (USNM Loc. 25a) in 1912, but my own collections and observations do not confirm its presence.

Holotype.—USNM 17440a (fide Walcott, 1912).

Type locality.—USNM Loc. 38a, two miles south of North Granville, New York.

Medusa? sp. (see **Tuzoia vermontensis**)

Mesonacis vermontana (see **Olenellus vermontanus**)

Microdiscus parkeri (see **Pagetides parkeri**)

Micromitra (*Paterina*) *bella* (see **Paterina bella**)

Micromitra (*Paterina*) *labradorica swantonensis* (see **Paterina labradorica swantonensis**)

NISUSIA FESTINATA (Billings), 1861 (Brachiopod)

Pl. 76, figs. 3–6

Orthisina festinata BILLINGS, 1861, Geol. Survey Canada, Palaeozoic Fossils, vol. 1, pt. 1, p. 9, figs. 10–12. ——, BILLINGS, 1862, Am. Jour. Sci., 2d Ser., vol. 33, pp. 102, 104, 105. As *Orthisinia festinata* on p. 104. ——, BILLINGS, in Hitchcock and others, 1862, Geology of Vermont, vol. 2, p. 949, figs. 350–352. ——, LOGAN, 1863, Geology of Canada, figs. 289a–c p. 284 (no text). ——, WALCOTT, 1886, U. S. Geol. Survey Bull. 30, pp. 120–121, pl. 7, figs. 7, 7a–b. ——, MILLER, 1889, North American Geology and Palaeontology, p. 360, Cincinnati, Ohio. ——, WALCOTT, 1891, U. S. Geol. Survey 10th Ann. Rept., pt. 1, p. 613, pl. 72, figs. 7, 7a–b.

Billingsella festinata HALL & CLARKE, 1892, Palaeontology of New York, vol. 8, pt. 1, p. 230.

Nisusia festinata WALCOTT, 1905, U. S. Nat. Mus. Proc., vol. 28, no. 1395, pp. 249–251. ——, WALCOTT, 1912, U. S. Geol. Survey Mon. 51, pp. 727–729, pl. 100, figs. 1–1j, 2–2c. ——, SCHUCHERT & COOPER, 1932, Peabody Mus. Yale Univ. Mem., vol. 4, pt. 1, pp. 44, 45, pl. 1, figs. 16, 20. ——, SHIMER & SHROCK, 1944, Index Fossils of North America, p. 293, p. 110, figs. 5–7, John Wiley, New York.

[not] *Nisusia festinata* KINDLE & TASCH, 1948, Canadian Field-Naturalist, vol. 62, p. 138, pl. 3, figs. 10–12.

This species is characteristic of the lower parts of the Parker slate and may be recognized by its transverse shape, costae of irregular thickness and by its hinge, which is the widest part of the shell.

Nisusia transversa has a transverse shape and finer, more regular ribbing than *N. festinata*.

In the upper Parker, two other *Nisusia* are found:

Nisusia, n. sp. has fine costellate to capillate ribbing and is not transverse as is *N. transversa*.

N. aff. *N. amii* shows the coarse irregular ribbing of *N. festinata*, but the greatest width of the shell lies anterior to the hinge line (Pl. 76, figs. 7, 8).

Holotype of Nisusia festinata.—Missing (W. A. Bell, letter, Sept, 9, 1952)

Type locality.—"1½ miles east of Swanton." (USNM Loc. 319e). Lower Parker slate.

Stratigraphic range.—Upper Dunham dolomite through the Parker slate. Most common brachiopod in lower Parker; rare in upper Parker. Kindle and Tasch indentified shells of a *Nisusia* 50-100 feet above the base of the Monkton quartzite with *N. festinata*, but the shape does not seem to permit the specimens to be placed in this species and the preservation of the surface is so poor as to prohibit placement elsewhere (Shaw, 1954, pp. 1036, 1037, 1038, 1039, 1040, 1042, 1043).

Nisusia festinata var. *transversa* (see **Nisusia transversa**)

Nisusia? orientalis (see **Wimanella? orientalis**)

NISUSIA TRANSVERSA (Walcott), 1886
(Brachiopod)
Pl. 76, fig. 9

Orthisina? transversa WALCOTT, 1886, U. S. Geol. Survey Bull. 30, p. 121, pl. 7, figs. 5, 5a. *Orhisina transversa* MILLER, 1889, North American Geology and Palaeontology, p. 360, Cincinnati, Ohio. ——, WALCOTT, 1891, U. S. Geol. Survey 10th Ann. Rept., pt. 1, p. 613, p. 72, figs. 9, 9a.
Billingsella transversa SCHUCHERT, 1897, U. S. Geol. Survey Bull. 87, p. 159.
Nisusia festinata var. *transversa* WALCOTT, 1905, U. S. Nat. Mus. Proc., vol. 28, no. 1395, p. 251.
Nisusia festinata transversa WALCOTT, 1912, U. S. Geol. Survey Mon. 51, vol. 1, p. 729, vol. 2, pl. 100, figs. 4, 4a–b.
Nisusia transversa SCHUCHERT & COOPER, 1932, Peabody Mus. Nat. History Yale Univ. Mem., vol. 4, pt. 1, p. 45.

For a discussion of this species see the comments under *Nisusia festinata*.

Holotype.—USNM 15361a; paratype USNM 15361b (Walcott, 1912, vol. 2, p. 336).

Type locality.—Original description says "silico-argillaceous shales of Parker's quarry" which would probably be USNM Loc. 319m. Walcott (1912, p. 729) says USNM Loc. 25, sandstone above Parker quarry, 170–210 feet above base of the Parker slate.

Known stratigraphic range.—SA-C-5, 8 to 10 feet above base of Parker slate to USNM Loc. 25(?), 170 to 210 feet above the base (Shaw, 1954, pp. 1039, 1040, 1042).

Obolella cingulata (see **Kutorgina cingulata**)

OBOLELLA CRASSA (Hall), 1847
(Brachiopod)

Orbicula? crassa HALL, 1847, Palaeontology of New York, vol. 1, p. 290, pl. 79, fig. 8a. A fig. 8b is listed on p. 290, but none appears on the plate.
Obolella crassa WALCOTT, 1912, U. S. Geol. Survey Mon. 51, pp. 251, 299, 592–595, pl 54, figs 2, 2a–n, text-fig 14. Complete synonymy.

This species was reported by Walcott (1912, p. 251) from USNM Loc. 319k, which lies 450 to 625 feet below the top of the Dunham dolomite in "calcareous sandstone near the base of the section west of Parker's quarry, on cliff overlooking Lake Champlain. . . ."

Since *O. crassa* has now become more or less of a wastebasket name it is not certain that the identification is correct in modern terms; no other record of the species is known.

Holotype.—NYSM 7850/1 (Clarke & Ruedemann, 1903, p. 265).

Type locality.—". . . in the intercalated calcareous strata, among the shales of the Hudson—river group, two miles northeast of Troy" New York.

Genus OLENELLUS Billings, 1861

Olenus HALL, 1859, New York State Cab. Nat. History 12th Ann. Rept., pp. 59–60.
Olenus HALL, 1859, Paleontology New York, vol. 3, pt. 1, pp. 525–526.
Barrandia HALL (not McCoy), 1860, New York State Cab. Nat. History 13th Ann. Rept., pp. 115–116.
Paradoxides BARRANDE, 1861, Soc. Géol. France Bull., 2d ser., vol. 18, pp. 276–278. ——, BILLINGS, 1861, Geol. Survey Canada, Palaeozoic Fossils, vol. 1, pt. 1, p. 10.
Olenellus BILLINGS, 1861, Geol. Survey Canada, Palaeozoic Fossils, vol. 1, pt. 1, footnote on p. 10. Validates the name according to Opinion of the I.R.Z.N.
Barrandia HALL (not McCoy), in Hitchcock and others, 1862, Rept. Geology of Vermont, vol. 1, pp. 369–370.
Paradoxides BILLINGS, in Hitchcock and others, 1862, Rept. Geology Vermont, vol. 2, p. 950.
Olenellus HALL, 1862, New York State Cab. Nat. History 15th Ann. Rept., p. 114. ——, WHITFIELD, 1884, Am. Mus. Nat. History Bull., vol. 1, no. 5, art. 7, pp. 151–153.
Mesonacis WALCOTT, 1885, Am. Jour. Sci., 3d. ser, vol. 29, p. 328. ——, WALCOTT, 1887, U. S. Geol. Survey Bull. 30, p. 158.
Olenellus WALCOTT, 1887, op. cit., pp. 162–166.
Olenellus (*Mesonacis*) WALCOTT, 1890, U. S. Nat. Mus. Proc. (1889), vol. 12, no. 763, pp. 40–41.
Olenellus WALCOTT, 1891, U. S. Geol. Survey 10th Ann. Rept., pt. 1, p. 633–635.
Olenellus (*Mesonacis*) WALCOTT, 1891, op. cit., p. 637.
Mesonacis WALCOTT, 1910, Smithsonian Misc. Coll., vol. 53, no. 6, pp. 261–262.
Paedeumias WALCOTT, 1910, op. cit., p. 304.
Olenellus WALCOTT, 1910, op. cit., pp. 311–314.
Mesonacis RESSER, 1928, Smithsonian Misc. Coll., vol. 81, no. 2, pp. 3–4, 5.
Paedeumias RESSER, 1928, op. cit., pp. 4–5.
Olenellus RESSER, 1928, op. cit., p. 5. ——, RAYMOND, 1928, Am. Jour. Sci., 5th ser., vol. 15, p. 169, ——, BELL, 1931, Am. Mus. Nat. History Novitates 485, 23 pp.
Mesonacis BELL, 1931, op. cit.
Olenellus RESSER & HOWELL, 1938, Geol. Soc. America Bull., vol. 49, pp. 217–218.

Paedeumias RESSER & HOWELL, 1938, op. cit., pp. 225–226.

The synonymy given above is restricted to references dealing primarily with Vermont or to fundamental discussions of the genus and is, thus, far from exhaustive, but it is indicative of the amount of consideration already given to this genus.

Walcott (1910, p. 304) gave the standard definition of the Olenellidae and recognized three genera which he diagnosed as follows:

Mesonacis has a spine-bearing fifteenth segment with ten smaller but typical thoracic segments and a pygidium characterized by postero lateral spines.

Paedeumias has the fourteenth segment as a median spine posterior to which there are from two to six rudimentary segments, and a rudimentary pygidium.

Olenellus has the fifteenth segment as a terminal telson without segments or pygidium posterior to it.

Raymond (1928, p. 169) noted that Walcott's concept of *Olenellus* was that based on incomplete specimens in which the segments behind the fifteenth were wanting, and this has been confirmed by Resser & Howell (1938, p. 217); all three authors have suppressed *Mesonacis* as a synonym of *Olenellus*, an opinion followed here.

Similarly, it seems to me that *Paedeumias* may well be suppressed as a synonym of *Olenellus*. Resser & Howell (1938, p. 226) state that "*Paedeumias* differs little from *Olenellus* except in the position of the glabella and the stalked hypostoma," but the position of the glabella varies within *Olenellus* from the full-length type of *O. thompsoni* (Resser & Howell, 1938, pl. 3, figs. 17–19) to short type of *O. schucherti* (op. cit., pl. 8, fig. 17). *O. thompsoni* itself has a glabellar shape ranging from that shown by the holotype to that shown by "*O. agellus*" (op. cit., pl. 9, fig. 11), which seems to be based on a variation of *O. thompsoni* and is not here regarded as a valid species.

The stalked hypostoma *may* be of generic significance, but at present it has not been established that the stalk is not present in those species of *Olenellus* whose glabella does not reach the anterior rim; it does not seem advisable at present to recognize a genus on such an uncertain basis, and *Paedeumias* is here suppressed. However, this does not indicate agreement with Weller (1949, p. 688) who suggests that genera should not be recognized on such a rarely preserved part as the hypostoma, for if the hypostoma *is* generically important in some trilobite, then it should be used, for genera reflect a biologic fact, not a type of preservation. But in the case of *Paedumias* and *Olenellus* I doubt that sufficient data are on hand to prove that the stalked hypostoma is always useful in generic separation.

In northwestern Vermont there seem to be four species of *Olenellus* present: *O. thompsoni* (Hall), 1859, *O. vermontanus* (Hall), 1859, *O. brachycephalus* (Emmons), 1860, and *O. hermani* Kindle & Tasch, 1948. *Paedeumias transitans* Walcott, 1910, *Olenellus agellus* Resser & Howell, 1938, and *Paedeumias perkinsi* Resser & Howell, 1938, have been recognized, but they seem to be based upon individual variants of *O. thompsoni*, *O. thompsoni*, *O. vermontanus*, and *O. brachycephalus* respectively.

Olenellus agellus (see **Olenellus thompsoni**)

OLENELLUS BRACHYCEPHALUS (Emmons), 1860 (Trilobite)
Pl. 75, figs. 1–3

Paradoxides brachycephalus EMMONS, 1860, Manual of Geology, text-fig. 70, p. 88, Philadelphia. Legend of text-fig. on p. 87 refers to figure as *Paradoxides asaphoides*.

Paradoxides macrocephalus BARRANDE, 1861, Soc. Géol. France Bull., 2d ser., vol. 18, pp. 276–277, pl. 5, fig. 7.

Barrandia vermontana HALL, in Hitchcock and others, 1862 (part), Rept. Geology Vermont, vol. 1, p. 370, pl. 13, figs. 4, 5 only. Fig. 2 = *O. vermontanus*.

Olenellus thompsoni WHITFIELD, 1884, Am. Mus. Nat. History Bull., vol. 1, no. 5, art. 7, pp. 151–153, pl. 15, figs. 1–4 (figs. 2–4 called *O. Vermontana* on plate legend, but species is suppressed in text discussion).

Paedeumias transitans WALCOTT, 1910, Smithsonian Misc. Coll. vol. 53, no. 6, pp. 305–310, pl. 34, fig. 1 only. Pl. 24, fig. 12, pl. 33, fig. 1, pl. 44, fig. 7 = *O. thompsoni* (Hall). Pl. 25, figs. 19–22; pl. 32, figs. 1–13; pl. 34, figs. 2–8 = *O. glabrus* (Resser & Howell) and *Olenellus yorkensis* (Resser & Howell). Pl. 33, figs. 2–5 unassigned.

Olenellus thompsoni RAYMOND, 1928, Am. Jour. Sci., 5th ser., vol. 15, p. 169. ——, BELL, 1931, Am. Mus. Novitates 475, text-figs. 1, 2, 4. Fig. 3 = *Olenellus* sp. indet.

Paedeumias transitans RESSER & HOWELL, 1938

Geol. Soc. America Bull., vol. 49, p. 226, pl. 8, fig. 13.
Paedeumias perkinsi RESSER & HOWELL, 1938, op. cit., p. 226, pl. 8, fig. 1.
Olenellus thompsoni KINDLE & TASCH, 1948 (part), Canadian Field-Naturalist, vol. 62, pp. 135–136, pl. 1, fig. 4 only, Pl. 2, fig. 4 = *Olenellus* sp. indet.
Olenellus vermontanus KINDLE & TASCH, 1948, op. cit., p. 136, pl. 1, figs. 5, 6.
Olenellus brachycephalus SHAW, 1954, Geol. Soc. America Bull., vol. 65, pp. 1041, 1044.
[not] *Paedeumias transitans* WALCOTT, 1910, Smithsonian Misc. Coll., vol. 53, no. 6, pl. 24, fig. 12; pl. 44, fig. 7 [= *O. thompsoni*].

Diagnosis.—*Olenellus* with four rudimentary segments back of the fifteenth thoracic segment, plus the pygidium (one more than in *O. thompsoni*). Eyes long as in *O. thompsoni*. Glabella consistently short of anterior border and with a somewhat smaller anterior lobe than *O. thompsoni* or *O. vermontanus*. Second pair of glabellar furrows from the front are short as in *O. vermontanus*.

Attempts to separate *Paedeumias perkinsi* in the collections at hand have led me to believe that that species is no more than an arbitrarily separated variant of *O. brachycephalus*.

It should be noted that *Paedeumias transitans*, the name by which this species is commonly known, is a synonym of *Paradoxides brachycephalus*, Emmons, 1860 (= *Paradoxides macrocephalus* Barrande, 1861).

Holotype.—Lost. An effort was made to locate Emmons' type, but it was not successful.

Lectotype of Paedeumias transitans.—USNM 56808b. (Resser and Howell, 1938, p. 226).

Type locality.—Presumably Parker quarry, about 150 feet above the base of the Parker slate.

Stratigraphic range.—Kelly-Parker zone, 140 to 210 feet above the base of the Parker, Monkton quartzite, 50–100 feet above base. This species was reported under the names *Olenellus thompsoni* and *O. vermontanus* from the Monkton formation by Kindle & Tasch, but their specimens all show the short glabella and small anterior glabellar lobe of *O. brachycephalus* (Shaw, 1954, pp. 1041, 1044).

Olenellus crassimarginatus (see **Olenellus thompsoni**)

Olenellus georgiensis (see **Olenellus vermontanus**)

OLENELLUS HERMANI Kindle & Tasch, 1948 (Trilobite)

Olenellus hermani KINDLE & TASCH, 1948, Canadian Field-Naturalist, vol. 62, pp. 136–137, pl. 1, figs. 1–3.
Olenellus hermani TASCH, 1952, Jour. Paleontology, vol. 26, p. 486, fig. 1–l.

Diagnosis.—*Olenellus* with a spine projecting backward from the rear edge of the anterior glabellar lobe, which is transversely oval. Second pair of glabellar furrows behind anterior lobe continuous across glabella and almost straight.

This species has been found only in the Monkton quartzite. Its small size and spinose glabella suggest immaturity, but it seems to be a different species from any others in Vermont by virtue of its unusual glabellar structure.

Holotype.—Private collection of Cecil H. Kindle.

Type and only known locality.—Knoll 2.34 miles N89½°E of Clay Point on Lake Champlain, Colchester township, Vermont (Kindle & Tasch, 1948, fig. 1. p. 134), 50–100 feet above base of Monkton quartzite.

OLENELLUS THOMPSONI (Hall), 1859 (Trilobite)

Olenus thompsoni HALL, 1859, New York State Cab. Nat. History 12th Ann. Rept., pp. 59–60, text-fig. 1. Same note also in Paleontology of New York, vol. 3, pt. 1, pp. 525–526, text-fig. 1, 1859.
Barrandia thompsoni HALL, 1860, New York State Cab. Nat. History 13th Ann. Rept., pp. 115–116, text-fig.
Paradoxides thompsoni BARRANDE, 1861, Soc. Géol. France Bull., 2d ser., vol. 18, p. 276, pl. 5, fig. 6.
Paradoxides Thompsoni BILLINGS, 1861, Canada Geol. Survey, Palaeozoic Fossils, vol. 1, pt. 1, p. 10. In footnote on same page Billings validates the generic name *Olenellus* for this species. ——, BILLINGS, 1861, Am. Jour. Sci., 2d ser., vol. 33, pp. 101, 102, 104. ——, BILLINGS, in Hitchcock and others, 1862, Rept. Geology Vermont, vol. 2, p. 950.
Olenellus thompsoni HALL 1862, New York State Cab. Nat. History 15th Ann. Rept., p. 114. ——, BILLINGS, 1865, Canada Geol. Survey, Paleozoic Fossils, vol. 1, p. 11. Revised printing of 1861 publication. ——, WALCOTT, 1887, U. S. Geol. Survey Bull. 30, pp. 167–168, pl. 17, figs. 1, 2; pls. 22, 23.
Elliptocephala thompsoni MILLER, 1889, North American Geology and Palaeontology, p. 546, fig. 1003 (Walcott's reconstruction), p. 546, Cincinnati, Ohio.

Olenellus thompsoni WALCOTT, 1891, U. S. Geol. Survey 10th Ann. Rept., pt. 1, p. 635, pl. 82, fig. 1, 1a(?), pl. 83. ——, WALCOTT, 1910, Smithsonian Misc. Coll., vol. 53, no. 6, pp. 336–340, pl. 35, figs. 3 (?), 4 (?).
Paedeumias transitans WALCOTT, 1910, op. cit., pl. 24, fig. 12; pl. 33, fig. 1; pl. 44, fig. 7.
Olenellus thompsoni var. *crassimarginatus* WALCOTT, 1910, op. cit., pp. 304–341, pl. 35, fig. 8.
Olenellus thompsoni RESSER & HOWELL, 1938, Geol. Soc. America Bull., vol. 49, pp. 219–220, pl. 3, figs. 17–19, text-fig. 1 (1).
Olenellus agellus RESSER & HOWELL, 1938, op. cit., p. 223, pl. 9, figs. 11–13.
Olenellus crassimarginatus RESSER & HOWELL, 1938, op. cit., p. 224, pl. 7, fig. 2.
[not] *Barrandia Thompsoni* HALL, in Hitchcock and others, 1862, Rept Geology Vermont, vol. 1, pl. 13, fig. 1, no text [=*O. vermontanus*].
[not] *Olenellus thompsoni* WHITFIELD, 1884, Am. Mus. Nat. History Bull., vol. 1, no. 5, art. 7, pp. 151–153, pl. 15, figs. 1–4=[*O. brachycephalus*.]
[not] *Olenellus thompsoni* RAYMOND, 1928, Am. Jour. Sci., 5th ser., vol. 15, p. 169 [=*O. brachycephalus*].
[not] *Olenellus thompsoni* BELL, 1931, Am. Mus. Novitates 475, text-figs. 1, 2, 4=[*O. brachycephalus*]. Fig. 3=*Olenellus* sp. indet.
[not] *Olenellus thompsoni* KINDLE & TASCH, 1948, Canadian Field-Naturalist, vol. 62, pp. 135–136, pl. 1, fig. 4 [=*O. brachycephalus*]; pl. 2, fig. 4 [=*Olenellus* sp. indet].

Diagnosis.—*Olenellus thompsoni* is a somewhat variable species, but it may be distinguished by the presence of three rudimentary segments and a pygidium behind the fifteenth, spine-bearing segment. The eyes are long, the rear ends lying opposite the occipital segment. The anterior glabellar lobe is large. Second pair of furrows behind anterior lobe is long, unlike *O. brachycephalus* or *O. vermontanus*.

Olenellus agellus Resser & Howell was erected for specimens in which the glabella does not reach the anterior rim. The large series of specimens in the Museum of Comparative Zoology shows that there is a gradation from the typical, full-length *O. thompsoni* glabella to the *O. agellus* type so that the latter seems to be based only on individual variations.

Likewise, *Olenellus thompsoni* var. *crassimarginatus* Walcott is based on what appears to be an individual variant showing a wide rim, and for that reason does not seem to warrant the recognition as a distinct species given it by Resser & Howell (1938, p. 224). It is here suppressed as an *O. thompsoni*.

Holotype.—ANMH 244 missing (O. H. Haas, letter, Nov. 26, 1951); casts USNM 4795, 62474 (Resser & Howell, 1938).

Type locality.—Parker quarry (USNM Loc. 319m) approximately 150 feet above base of Parker slate.

Stratigraphic range.—Lower Parker slate. May range downward into the Dunham and Gilman. Absent in the upper Parker. Kindle & Tasch (1948, pp. 135–136) have reported this species from the Monkton quartzite, but their first illustration shows a glabella bearing the small frontal lobe and discontinuous second pair of glabellar furrows that characterize *Olenellus brachycephalus*, and their second figure is of an unidentifiable fragment, so that the presence of *O. thompsoni* in the Monkton cannot be regarded as demonstrated, although it would not be surprising to find it there.

Olenellus thompsoni var. *crassimarginatus* (see **Olenellus thompsoni**)

OLENELLUS VERMONTANUS (Hall), 1859
1859 (Trilobite)
Pl. 75, fig. 10

Olenus vermontanus HALL, 1859, New York State Cab. Nat. History 12th Ann. Rept., pp. 60–61, text-fig. 2. Same note published in Paleontology of New York, vol. 3, pt. 1, p. 527, text-fig. 2, 1859.
Barrandia vermontana HALL, 1860, New York State Cab. Nat. History 13th Ann. Rept., pp. 117–118.
Paradoxides vermontana BARRANDE, 1861, Soc. Géol. France Bull., 2d ser., vol. 18, pp. 277–278, pl. 5, fig. 8. ——, BILLINGS, 1861, Canada Geol. Survey Palaeozoic Fossils, vol. 1, pt. 1, p. 11.
Paradoxides Vermontana BILLINGS, 1862, Am. Jour. Sci., 2d ser., vol. 33, pp. 101, 102, 104.
Barrandia vermontana HALL, in Hitchcock and others, 1862, Rept. Geology Vermont, vol. 1, p. 370, pl. 13, fig. 2 only. Figs. 4, 5=*Olenellus brachycephalus*.
Barrandia Thompsoni HALL, in Hitchcock and others, 1862, Rept. Geology Vermont, vol. 1, pl. 13, fig. 1, no text.
Paradoxides vermontana BILLINGS, in Hitchcock and others, 1862, Rept. Geology Vermont, vol. 2, p. 950.
Olenellus vermontanus BILLINGS, 1865, Canada Geol. Survey, Palaeozoic Fossils, vol. 1, p. 11, Revision of Billings, 1861.
Mesonacis vermontana WALCOTT, 1885, Am. Jour. Sci., 3rd ser., vol. 29, pp. 328–330, figs. 1, 2. ——, WALCOTT, 1886, U. S. Geol. Survey Bull. 30, pp. 158–159, pl. 24, figs. 1, 1a–b. ——, MILLER, 1889, North American Geology and Palaeontology, p. 556, fig. 1031, Cincinnati, Ohio.
Olenellus (*Mesonacis*) *vermontana* WALCOTT,

1891, U. S. Geol. Survey 10th Ann. Rept., pt. 1, p. 637, pl. 87, figs. 1, 1a–b.

Mesonacis vermontana WALCOTT, 1910, Smithsonian Misc. Coll., vol. 53, no. 6, pp. 264–266, pl. 26, figs. 1–3, pl. 44. fig. 2. ——, WALCOTT, 1917, Smithsonian Misc. Coll., vol. 67, no. 3, p. 66, pl. 9, fig. 3.

Olenellus georgiensis RESSER & HOWELL, 1938, Geol. Soc. America Bull., vol. 49, p. 220, pl. 5. figs. 6, 7.

Olenellus vermontanus RESSER & HOWELL, 1938, op. cit., pp. 220–221, pl. 4, figs. 15–16, text-fig. 1 (2).

[not] *Olenellus vermontanus* KINDLE & TASCH, 1948, Canadian Field-Naturalist, vol. 62, p. 136, pl. 1, figs. 5, 6 = *O. brachycephalus*.

Diagnosis.—*Olenellus* with ten thoracic segments and a pygidium behind the spined fifteenth segment. The eyes are short with the posterior extremities lying opposite the pre-occipital lobe of the glabella, unlike *O. thompsoni*. Glabella long, with second pair of furrows behind anterior lobe short and incomplete.

O. georgiensis Resser & Howell, 1938, was erected for specimens with the thoracic number as found in *O. vermontanus* but of broader proportions. I believe that the difference between the species is due to the fact that specimens of *O. georgiensis* died facing east-west and those of *O. vermontanus* faced north-south. Compression at the Parker Quarry was from the east.

Holotype.—ANMH 230 (missing); cast USNM 62475 (Resser & Howell, 1938).

Type locality.—Parker Quarry (USNM Loc. 25), approximately 150 feet above the base of the Parker.

Stratigraphic range.—Known certainly only at type locality and from the single glabella figured in this report from the slate at Kelly Quarry (Locality SA-C-1), 150–160 feet above the base of the Parker slate. This species was reported by Kindle & Tasch from the Monkton, but their specimens are here identified with *O. brachycephalus*.

Olenoides (*dorypyge*) *desiderata* (see **Bonniella desiderata**)

Olenoides marcoui (see **Kootenia marcoui**)

Olenus thompsoni (see **Olenellus thompsoni**)

Olenus vermontanus (see **Olenellus vermontanus**)

Orbicula caelata (see **Botsfordia caelata**)

Orthisina festinata (see **Nisusia festinata**)

Orthisina orientalis (see **Wimanella? orientalis**)

Orthisina transversa (see **Nisusia transversa**)

Paedeumias perkinsi (see **Olenellus brachycephalus**)

Paedeumias transitans (see **Olenellus brachycephalus** and **O. thompsoni**)

PAGETIDES PARKERI (Walcott), 1886
(Trilobite)
Pl. 74 fig. 13;
Pl. 75 figs. 4–9

Microdiscus parkeri WALCOTT, 1886, U. S. Geol. Survey Bull. 30, pp. 157–158, pl. 16, figs. 2, 2a. ——, MILLER, 1889, North American Geology and Palaeontology, p. 557, Cincinnati, Ohio. ——, WALCOTT, 1891, U. S. Geol. Survey 10th Ann. Rept., pt. 1, p. 632, pl. 80, figs. 7, 7a.

Goniodiscus parkeri RAYMOND, 1913, Ottawa Naturalist, vol. 27, p. 104, text-fig. 13.

Calodiscus parkeri KOBAYASHI, 1943, Imp. Acad. Tokyo Proc., vol. 19, no. 1, p. 38. ——, KOBAYASHI, 1944, Imp. Univ. Tokyo Jour. Fac. Sci., sec. 2, vol. 7, pt. 1, pp. 29, 36, 47, 49, pl. 2, figs. 13a, b.

Pagetides elegans RASETTI, 1945, Am. Jour. Sci., vol. 243, p. 313, pl. 1, figs. 15–18. ——, RASETTI 1948, Jour. Paleontology, vol. 22, p. 11, pl. 1, figs. 1–7. Figs. 4–6 from Kelly quarry (Locality SA-C-1).

Pagetides parkeri RASETTI, 1952, Jour. Paleontology, vol. 26, pp. 439–440. ——, SHAW, 1954, Geol. Soc. America Bull., vol. 65, pp. 1040, 1041.

The history of this little species is confused, and it has been discussed by Rasetti (1952, pp. 439–440), who found that the type lot contains nine specimens comprising one furrowed pygidium, seven smooth pygidia and one cranidium. These, Rasetti separated into two species, restricting the name *P. parkeri* to the smooth internal pygidial molds.

The present collections contain 40 cranidia and 50 pygidia of this species, and a study of these specimens shows that the furrowed and smooth pygidia do not belong to separate species but are the end members of a continuous morphologic series. Internal molds are most commonly furrowed, but there is a gradation through faintly furrowed specimens to those that are virtually smooth, although on the best-preserved "smooth" molds some trace of the furrows is still faintly visible. The external molds, on the other hand, are commonly smooth, but they grade into rare individuals that are faintly furrowed. Thus, the furrowed and smooth internal molds found in the type lot seem to belong to one and not two

species. This conclusion is supported by the fact that only one head is present and in numbers essentially equal to the tail. The loss of the free cheeks seems to have weakened the head somewhat and would account for the slightly fewer cranidia found. The head has been assigned to *Pagetides elegans* by Rasetti (1948, pl. 1, figs, 4–6).

Thus, it seems that only one species is present and that *P. elegans* Rasetti is synonymous with *P. parkeri* (Walcott). It is unfortunate that the well-established species *P. elegans* must be dropped in favor of the more poorly defined *P. parkeri*, but there seems to be no alternative, if the interpretation outlined above is accepted. The effective description of the species will, of course, remain Rasetti's discussion of *P. elegans*. The species has been beautifully illustrated by Rasetti, including specimens from Kelly quarry, and there is no need to attempt to figure the species fully again, but a unique internal impression of a cephalon preserving the facial sutures as raised lines is figured together with an external cast of a pygidium to show the appearance of that part. Internal molds of the head and tail are figured for comparison with the specimens figured by Rasetti in 1948.

Lectotype.—Specimen figured by Walcott (1886, pl. 16, fig. 2). Chosen by Rasetti (1952, p. 440).

Type locality.—Parker quarry, about 150 feet above the base of the Parker slate.

Stratigraphic range.—Base of the Parker to the dolomite at Kelly quarry (Locality SA-C-1) about 165 feet above the base of the Parker. May range slightly higher, depending upon the position of the original specimens from Parker quarry (Shaw, 1954, 1040, 1041). Through an oversight the presence of a single pygidium at Locality M-NW-1, in the lower 10 feet of the Parker, was not noted in my earlier summary (op. cit., p. 1038).

Palaeophycus congregatus (see **Planolites congregatus**)

Palaeophycus incipiens (see **Planolites virgatus**)

Palaeophycus virgatus (see **Planolites virgatus**)

Paradoxides asaphoides (see **Olenellus brachycephalus**)

Paradoxides brachycephalus (see **Olenellus brachycephalus**)

Paradoxides macrocephalus (see **Olenellus brachycephalus**)

Paradoxides? quadrispinosus (see **Bathynotus holopygus**)

Paradoxides thompsoni (see **Olenellus thompsoni**)

Paradoxides vermontana (see **Olenellus vermontanus**)

PATERINA BELLA (Billings), 1872 (Brachiopod)

Iphidea bella BILLINGS, 1872, Canadian Naturalist, n. ser., vol. 6, pp. 477–478, fig. 13. ——, BILLINGS, 1874, Geol. Survey Canada Palaeozoic Fossils, vol. 2, pt. 1, p. 76, fig. 44. ——, WALCOTT, 1886, U. S. Geol. Survey Bull. 30, pp. 100–101, pl. 7, fig. 4. ——, MILLER, 1889, North American Geology and Palaeontology, p. 346, fig. 567, Cincinnati, Ohio. ——, WALCOTT, 1891, U. S. Geol. Survey 10th Ann. Rept., pt. 1, p. 608, pl. 67, fig. 6.

Micromitra (Paterina) bella WALCOTT, 1912, U. S. Geol. Survey Mon 51, vol. 1, pp. 344–345, vol. 2, pl. 2, figs. 1–1c.

Paterina bella SHAW, 1954, Geol. Soc. America Bull., vol. 65, p. 1040.

In 1886 Walcott stated that this species was not known in Vermont, but in 1912 he listed it from USNM locality 25, the "sandstone just above Parker's quarry." No specimens have been recovered during this study, nor has anyone ever figured one from Vermont, so we must regard the presence of the species as unconfirmed. A complete synonymy is not given.

Holotype.—missing in 1896 (Walcott, 1897, p. 708)

Type locality.—Trois Pistoles, Quebec.

PATERINA LABRADORICA SWANTONENSIS (Walcott), 1890 (Brachiopod)

Pl. 76, fig. 11

Kutorgina labradorica WALCOTT, 1886 (part), U. S. Geol. Survey Bull. 30, pl. 9, figs. 2, 2a–b. Not text, which refers to *K. labradorica.*

Kutorgina labradorica var. *swantonensis* WALCOTT 1890, U. S. Nat. Mus. Proc. (1889), vol. 12, p. 36. ——, WALCOTT, 1891. U. S. Geol. Survey 10th Ann. Rept. pt. 1, p. 609, pl. 69, figs. 2, 2a–b.

Paterina labradorica swantonensis BEECHER, 1891, Am. Jour. Sci., 3d ser., vol. 41, pp. 345–346 footnote, pl. 17, fig. 2.

Paterina labradorica HALL & CLARKE, 1892, 11th Ann. Rept. State Geologist New York for 1891, p. 247 fig. 258. Reprinted as 45th Ann. Rept. New York State Mus. for 1891, p. 563, fig. 258.

Paterina Swantonensis HALL & CLARKE, 1894, Palaeontology New York, vol. 8, pt. 2, p. 321, footnote.
Iphidea bella HALL & CLARKE, 1892, 11th Ann. Rept. State Geologist New York for 1891, p. 249, pl. 4, figs. 4, 5.
Iphidea labradorica var. *swantonensis* WALCOTT, 1897, U. S. Nat. Mus. Proc., vol. 19, no. 1120, pp. 708, 710.
Iphidea labradorica swantonensis Schuchert, 1897, U. S. Geol. Survey Bull. 87, p. 234.
Iphidella labradorica swantonensis WALCOTT, 1905, U. S. Nat. Mus. Proc., vol. 28, p. 307.
Micromitra (*Paterina*) *labradorica swantonensis* WALCOTT, 1912 U. S. Geol. Survey Mon. 51, pp. 348–349, pl. 2, figs. 3, 3a-f.
[?] *Paterina* cf. *swantonensis* KINDLE & TASCH, 1948, Canadian Field Naturalist, vol. 62, p. 138, pl. 3, fig. 15.

Only one ventral valve of this subspecies has been found in the collections available to me, but its presence in northwestern Vermont seems to be established.

Holotype.—USNM 15329.

Type locality.—Hall Farm (USNM Loc. 25a) (fide Walcott, 1912), about 450 feet above the base of the Parker slate. Original statement of locality (Walcott, 1890, p. 36) was "East of Swanton and Highgate Springs."

Stratigraphic range.—Walcott (1912) reported the species from USNM Loc. 26, somewhere in the top of the Dunham and USNM Locs. 87, 319y, and 319z, none of which can now be located geographically or stratigraphically. Provisionally identified in the lower Monkton by Kindle and Tasch (1948); the figured ventral valve was collected from Locality M-NC-12, 170 feet above the base of the Parker. Total range: upper Dunham through lower 450 feet of Parker slate.

Paterina swantonensis (see **Paterina labradorica swantonensis**)

PERIMETOPUS ARENOSUS (Billings), 1861 (Trilobite)

Conocephalites arenosus BILLINGS, 1861, Canada Geol. Survey Palaeozoic Fossils, vol. 1, pt. 1, p. 15, fig. 18. ——, BILLINGS, 1862, Am. Jour. Sci., 2d ser., vol. 33, p. 104. ——, BILLINGS, in Hitchcock and others, 1862, Rept. Geology Vermont, vol. 2, pp. 952–953, text-fig. 358. ——, LOGAN, 1863, Geology of Canada, fig. 297, p. 286.
Ptychoparia arenosa MILLER, 1889, North American Geology and Palaeontology, p. 565, Cincinnati, Ohio.
Solenopleura arenosa MATTHEW, 1897, Royal Soc. Canada Proc. and Trans. for 1897, 2d ser., vol. 3, pp. 182, 199–200, pl. 4, fig. 10.
Perimetopus arenosus RESSER, 1937, Jour. Paleontology, vol. 11, p. 51, pl. 8, figs. 50, 51.
Perimetopus secundus RESSER, 1937, op. cit., p. 51, pl. 8, fig. 49.

Resser has figured the two known specimens of this rare species under the two names listed above. *Perimetopus secundus* was erected on a supposedly "wider" cranidium, but the species seems poorly based and is here regarded as synonymous with *P. arenosus.*

Holotype.—NMC 428a (fide Resser, 1937).

Type and only known locality.—"In thin bedded flaggy sandstone by the side of the road leading from Moore's Corners in St. Armand to Saxe's Mill in Highgate, Vermont, about one mile south of the Province line" (Billings, 1861). This is Locality A of Shaw (1954, p. 1036) 550–600 feet below the top of the Dunham.

Perimetopus secundus (see **Perimetopus arenosus**)

PERIOMMA Resser, 1937

Periomma RESSER, 1937, Jour. Paleontology, vol. 11, p. 53.
Periommella RESSER, 1938, Geol. Soc. America Special Paper, 15, p. 93.
Periomma LOCHMAN, 1947, Jour. Paleontology, vol. 21, p. 67.
Periomella LOCHMAN, 1947, loc. cit.

It appears that the two genera erected by Resser are based on the same species found in separate states. Lochman has analyzed these genera and found that, based on the type specimens, *Periomma* has narrower fixed cheeks and a slightly narrower occipital ring than *Periomella.*

It seems probable that the extreme width of the fixed cheeks in the holotype of *Periomella yorkensis* is due to flattening, for the paratypes (Resser, 1938, pl. 3, fig. 36) show no such extreme expansion and are of the same relative width as those of the types of *Periomma typicalis* (Resser, 1937, pl. 8, figs. 56–58).

It seems, therefore, that the species *Periomella yorkensis* should be suppressed as synonymous with *Periomma typicalis.*

PERIOMMA TYPICALIS Resser, 1937
(Trilobite)
Pl. 74, fig. 10

Ptychoparia vulcanus WALCOTT, 1886 (part), U. S. Geol. Survey Bull. 30, pp. 198–199, pl. 26, fig. 4 only. Fig. 4a = *Antagmus? simplex*. ——, WALCOTT, 1891 (part), U. S. Geol. Survey 10th Ann. Rept., pt. 1, p. 653, pl. 96, fig. 4 only. Fig. 4a = *Antagmus? simplex*.
Ptychoparia adamsi WALCOTT, 1912, U. S. Geol. Survey Mon 51, p. 189 (cited from USNM loc. 28).
Acrocephalites? vulcanus WALCOTT, 1916, Smithsonian Misc. Coll., vol. 64, no. 3, p. 182, p. 26, fig. 2.
Periomma typicalis RESSER, 1937, Jour. Paleontology, vol. 11, p. 53, pl. 8, figs. 56–58.
Periomella yorkensis RESSER, 1938, Geol. Soc. America Special Paper 15, p. 93, pl. 3, figs. 35–36.
Periomma typicalis LOCHMAN, 1947, Jour. Paleontology, vol. 21, p. 67.
Periomella yorkensis LOCHMAN, 1947, Jour. Paleontology, op. cit., p. 68.

This is a rare member of the lower Parker fauna, being represented in present collections by a single specimen from Locality M-NC-2U, 140 feet above the base of the formation. The species was originally described (Resser, 1937, p. 58) from USNM Loc. 28, which is not geographically possible according to the directions given by Walcott (1912, p. 189); at Loc. 28 it is associated with *Hyolithes*, which is generally confined to the Lower Cambrian in Vermont, and *Protorthis wingi*, a brachiopod of uncertain affinities (Schuchert & Cooper, 1932, p. 47) and dubious age.

The outstanding features of the cranidium are the elevated fixed cheeks, prominent eye-lines and the posterior position of the eyes. Further, this is the only species in the Lower Cambrian of Vermont with a well-developed median boss except for *Billingsaspis adamsii*, which differs markedly from *P. typicalis* in the course of the facial sutures anterior to the eyes.

Holotype.—USNM 15437 (fide Resser, 1937).

Type locality.—USNM Loc. 28, which cannot be located, geographically or stratigraphically.

Stratigraphic range.—A single specimen found at M-NC-2U 140 feet above the base of the Parker slate, approximately at the Parker-Kelly quarry horizon.

Phyllograptus?? cambrensis (see **Emmonsaspis cambrensis**)

Phyllograptus? simplex (see **Emmonsaspis cambrensis**)

PLANOLITES CONGREGATUS (Billings), 1861 (Trail)

Paleophycus congregatus BILLINGS, 1861, Canada Geol. Survey Paleozoic Fossils, vol. 1, pt. 1, p. 3. ——, BILLINGS, 1862, Am. Jour. Sci. 2d ser., vol. 33, p. 104. ——, BILLINGS, in Hitchcock and others, 1862, Rept. Geology Vermont, vol. 2, p. 944. ——, WALCOTT, 1886, U. S. Geol. Survey Bull. 30, pp. 15, 45, 72.
Palaeophycus congregatum MILLER, 1889, North American Geology and Palaeontology, p. 130, Cincinnati, Ohio.
Planolites congregatus WALCOTT, 1890, U. S. Nat. Mus. Proc. (1889), vol. 12, pp. 34–35. ——, WALCOTT, 1891, U. S. Geol. Survey 10th Ann. Rept., pt. 1, p. 602, pl. 61, fig. 1.

(See comments under *Planolites virgatus*)

Cotype.—GSC 435a.

Type locality.—"By the side of the road leading from Moore's Corner's in St. Armand to Saxe's Mill, about a mile south of the International Boundary" (Locality A of Shaw (1954, p. 1036)), 550 to 600 feet below the top of the Dunham dolomite. Not seen elsewhere; reported at Parker quarry (USNM Loc. 319m) by Walcott (1912, p. 251).

Planolites incipiens (see **Planolites virgatus**)

PLANOLITES VIRGATUS (Hall), 1847
(Trail)

Palaeophycus virgatus HALL, 1847, Paleontology of New York, vol. 1, p. 263, pl. 70, fig. 1.
Palaeophycus incipiens BILLINGS, 1861, Canada Geol. Survey Palaeozoic Fossils, vol. 1, pt. 1, pp. 2–3. ——, BILLINGS, 1862, Am. Jour. Sci., 2d ser., vol. 33, pp. 102, 104. ——, BILLINGS, in Hitchcock and others, 1862, Rept. Geology Vermont, vol. 2, pp. 943–944. ——, WALCOTT, 1886, U. S. Geol. Survey Bull. 30, pp. 15, 45, 72.
Palaeophycus virgatum MILLER, 1889, North American Geology and Paleontology, p. 131, Cincinnati, Ohio.
Planolites incipiens WALCOTT, 1890, U. S. Nat. Mus. Proc. (1889), vol. 12, no. 763, p. 35. *Planolites virgatus* (Hall) WALCOTT, 1891, U. S. Geol. Survey 10th Ann. Rept., pt. 1, pp. 602–603, pl. 61, fig. 5.

It may be questioned whether trails such as this and *P. congregatus* should be given more than one name, or should even be named at all, and the separate listing given here does not imply acceptance of the two

names as valid species. It is certain that that such marks as these have little stratigraphic value, even locally, for specimens indistinguishable from *P. congregatus* have been found in slates provisionally referred to the Upper Cambrian (Dresbachian) Skeels Corners formation.

Holotype.—missing (W. A. Bell, letter, Sept. 9, 1952).

Type locality.—" . . . in the shales of this [Hudson River] group, in neighborhood of Union village and Salem, in Washington county" New York (Hall, 1847).

Stratigraphic range. USNM Loc. 26, at an unknown position below the top of the Dunham, at Parker quarry (USNM Loc. 319m) about 140 feet above the base of the Parker, and in the lower Upper Cambrian.

PROTOCARIS MARSHI Walcott, 1884
(Crustacean)

Protocaris marshi WALCOTT, 1884, U. S. Geol. Survey Bull. 10, pp. 330–331, pl. 10. ——, WALCOTT, 1886, U. S. Geol. Survey Bull. 30, p. 148, pl. 15. ——, MILLER, 1889, North American Geology and Palaeontology, p. 563, fig. 1049, Cincinnati, Ohio. ——, WALCOTT, 1891, U. S. Geol. Survey 10th Ann. Rept., pt. 1, p. 629, pl. 81, fig. 6.

Apus marshi BERNARD, 1894, Quart. Jour. Geol. Soc. London, vol. 50, p. 413.

Protocaris marshii SCHUCHERT, 1897, U. S. Nat. Mus. Proc., vol. 19, pp. 674–675, pl. 58, fig. 1.

Protocaris marshi RESSER, 1929, U. S. Nat. Mus. Proc., vol. 76, art. 9, pp. 12–13, pl. 6, figs. 1, 2. ——, RESSER & HOWELL, 1938, Geol. Soc. American Bull., vol. 49, p. 232, pl. 10, fig. 7, pl. 13, fig. 8.

There is nothing to add to the discussion and figures given by Schuchert, Resser, and Resser & Howell.

Holotype.—USNM 15400.

Type and only known locality.—Parker quarry, about 150 feet above the base of the Parker slate.

Protorhyncha? antiquata (see **Swantonia antiquata**)

"PROTORTHIS" WINFI Walcott, 1905
Brachiopod)

Protorthis wingi WALCOTT, 1905, U. S. Nat. Mus. Proc., vol. 28, p. 286. ——, WALCOTT, 1912, U. S. Geol. Survey Mon. 51, pp. 107, 189, 743, pl. 93, figs. 5, 5a-c.

"Prothorthis" wingi SCHUCHERT & COOPER, 1932, Peabody Mus. Nat. History Mem., vol. 4, pt. 1, p. 47.

This species does not belong to *Protorthis* as was pointed out by Schuchert & Cooper, but it is impossible now to place it correctly. The only known occurrence is at USNM Loc. 28, which, unfortunately, it is impossible to locate because the directions given by Walcott (1912, p. 189) present a geographic impossibility. However, at this locality *P. wingi* is associated with *Hyolithes*, which is common only in the Lower Cambrian in northwestern Vermont, and with *Periomma typicalis* (= *Ptychoparia adamsi* of Walcott, 1912, p. 189), which is a proved member of the lower Parker fauna. Therefore, it seems that, although Walcott dated the collection from Loc. 28 as Upper

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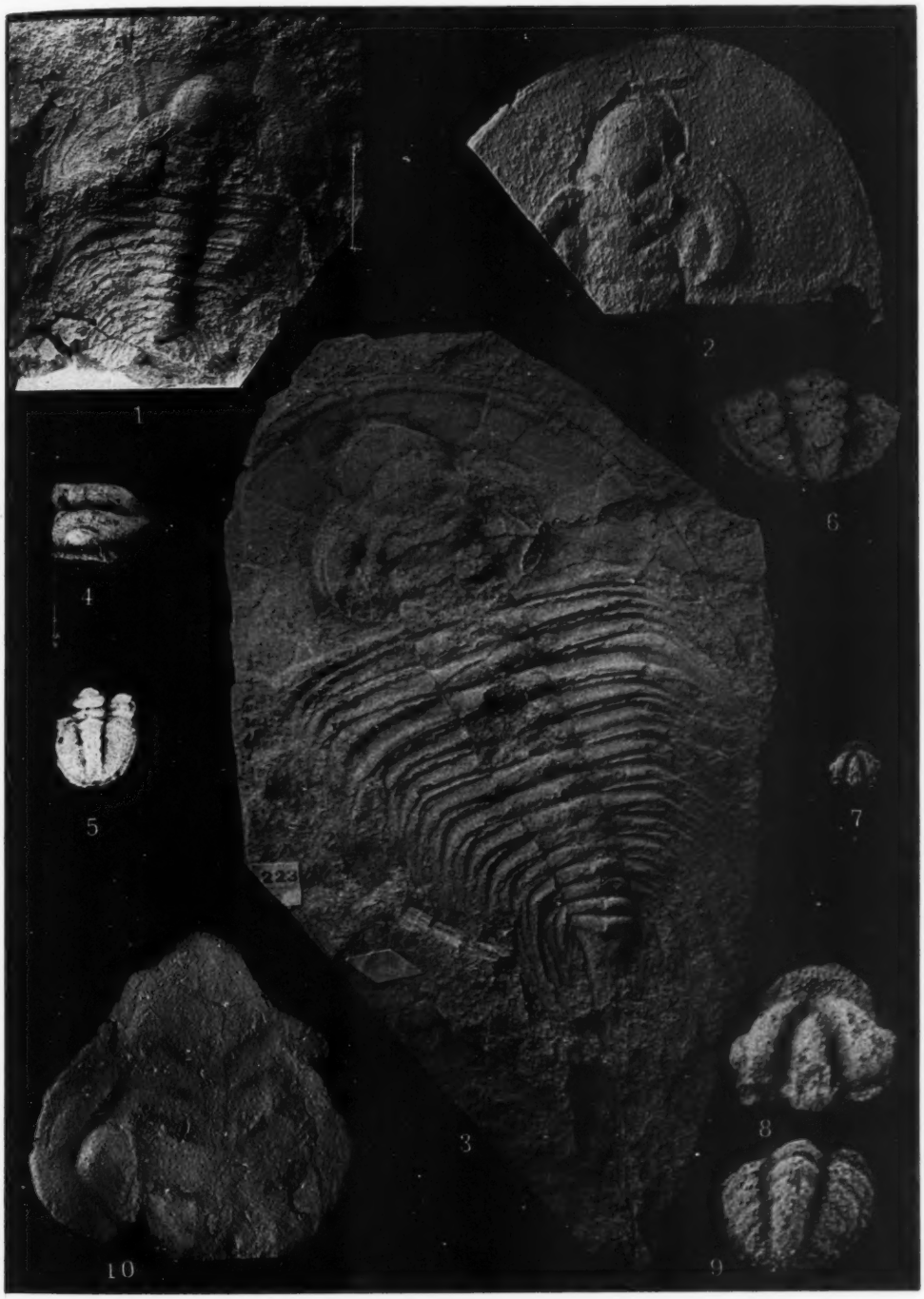
EXPLANATION OF PLATE 75

All specimens figured are natural internal molds except figs. 5 and 10, which are artificial casts. Figs. 1 and 4 have been retouched

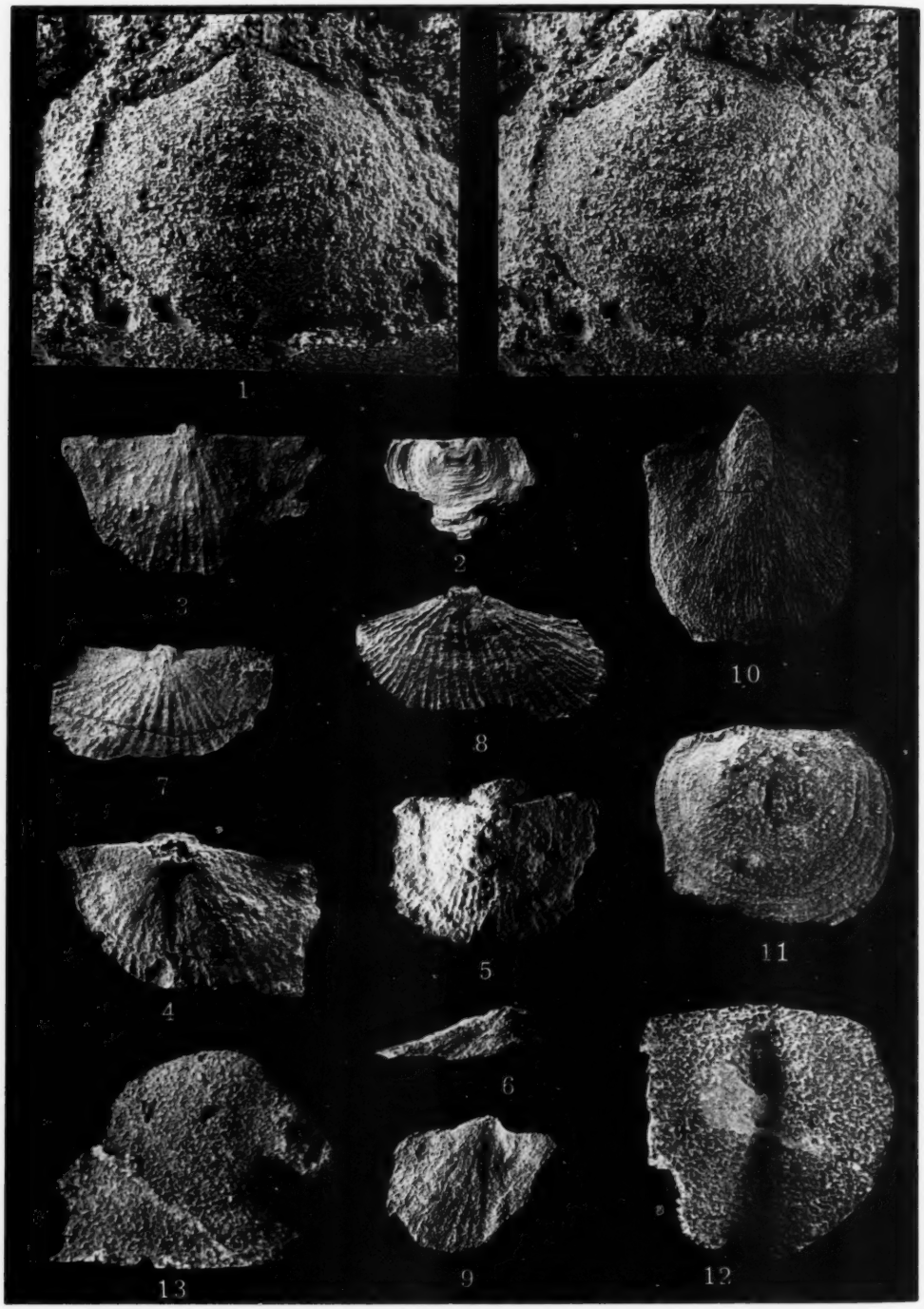
FIGS. *1–3*—*Olenellus brachycephalus* (Emmons), 1860. *1*, Small specimen (AMNH 227) showing trace of doublure impressed on dorsal cephalic surface. Figured as *Olenellus vermontanus* by Whitfield (1884, p. 15, fig. 2), ×1. *2*, Flattened cephalon (MCZ 4994) from Locality SA-C-1 (Kelly quarry slates) about 150–160 feet above base of Parker, ×2. *3*, Nearly complete specimen (AMHH 223) figured by Whitfield (1884, pl. 15, fig. 1) and Bell (1931, fig. 4) as *Olenellus thompsoni*, ×0.85. Figures *1* and *3* from Parker quarry (USNM Loc. 319g or 319m). (p. 791)

4–9—*Pagetides parkeri* (Walcott), 1886. *4*, Fragmentary cephalon showing right eye lobe and preserving facial sutures as ridges (U. Wyo. A215a), ×6. Photographed by P. E. Cloud, Jr. *5*, Rubber squeeze of natural external mold of thorax and pygidium, showing smooth pleural lobes (U. Wyo A215b), ×3. *6*, Unusual short, wide pygidium (MCZ 5037a), ×7½. *7, 8*, Cranidium (MCZ 5037c), ×2½ and ×7½. *9*, Normally ribbed internal pygidial mold (MCZ 5037b), ×8½. All specimens from Locality SA-C-1 (Kelly quarry slates) about 150–160 feet above base of Parker. (p. 794)

10—*Olenellus vermontanus* (Hall), 1859. Rubber squeeze (U. Wyo IT-180) of glabella (MCZ 4992) from Kelly quarry slates (see above), ×1. (p. 793)



Shaw, The Lower Cambrian fauna, Vermont



Shaw, The Lower Cambrian fauna, Vermont

Cambrian, *P. wingi* is in fact a Lower Cambrian species, albeit a rare one.

Holotype.—USNM 52437b (fide Walcott, 1912, vol. 2, p. 309).

Type and only known locality.—USNM Loc. 28, which cannot be located, geographically or stratigraphically.

Protypus hitchcocki (Whitfield), 1884 (Trilobite)
Pl. 74, fig. 9

Angelina hitchcocki Whitfield, 1884, Am. Mus. Nat. History Bull. vol. 1, no. 5, art. 7, pp. 148–150, pl. 14, fig. 3.

Protypus hitchcocki Walcott, 1886, U. S. Geol. Survey Bull. 30, pp. 211–213, pl. 31, fig. 4. ——, Miller, 1889, North American Geology and Palaeontology, p. 563, fig. 1050, Cincinnati, Ohio. ——, Walcott, 1891, U. S. Geol. Survey 10th Ann. Rept., pt. 1, p. 655, pl. 98, fig. 6. ——, Resser & Howell, 1938, Geol. Soc. America Bull., vol. 49, p. 230.

This species is known only from the holotype, collected by Marcou sometime prior to 1884 at the Parker quarry. Resser & Howell pointed out that Walcott's illustrations were incorrectly drawn, but did not publish a photograph of the cast. This cast is figured here through the courtesy of Dr. G. A. Cooper who arranged for it to be photographed.

Holotype.—ANMH 232 (missing); cast, USNM 15424.

Type and only known locality.—Parker quarry slates (USNM Loc. 319m) about 150 feet above the base of the Parker slate.

Protypus senectus (see **Bonnia capito**)

Prozancanthoides sp. indet.
Pl. 74, fig. 15

The internal impression of a single cranidium of this genus has been found in the Parker slate at Kelly quarry (Locality SA-C-1), approximately 155 feet above the base of the formation (Shaw, 1954, p. 1041).

The specimen is flattened and has developed two cross fractures on lines continuing the trend of the anterior branches of the facial sutures. The glabella is almost oblong, with a slight constriction in the posterior third. Four pairs of short, straight glabellar furrows are present as well as a straight, evenly impressed occipital furrow. The occipital ring bears a small, median, posterior node that may represent the site of an occipital spine.

Explanation of Plate 76

All specimens figured are natural internal molds except fig. 10, which shows the shell

Figs. *1, 2*—*Kutorgina cingulata* (Billings), 1861. *1*, Stereophotos of a sandstone impression of a ventral valve showing the pedicle opening at the ventral tip of the xenidium filled with matrix (MCZ 9351), ×4½. Locality SA-SC-14, from basal five feet of Parker. *2*, Plesiotype dorsal valve from Parker slate at "Swanton, Vermont," figured by Hall and Clarke (1892, pl. 2, fig. 17) (NYSM 7600/4), ×2. Print from negative supplied by Dr. R. H. Flower. (p. 787)

3–6—*Nisusia festinata* (Billings), 1861. *3*, Dorsal valve (MCZ 9349) showing tendency toward alation (note growth lines on right-hand side), ×2. From Locality M-NC-12, 170 feet above the base of the Parker. *4*, Ventral valve with xenidium (MCZ 9349b), ×2. Same locality as *3*. *5, 6*, Ventral and posterior views of rubber squeeze of ventral valve with xenidium (specimen now destroyed), ×2. From upper Parker slate (Middle Cambrian at Locality SA-EC-3 about 50 feet above the middle Parker dolomite. Introduced for comparison. (p. 789)

7, 8—*Nisusia* aff. *N. amii* Walcott, 1905. Two dorsal valves of the common species in the upper Parker slate, introduced for comparison with *N. festinata* and *N. transversa* (U. Wyo. IT-258p and IT-258k), ×2. Locality SA-EC-1, 190 feet above middle Parker dolomite. (p. 789)

9—*Nisusia transversa* (Walcott), 1886. Ventral valve (MCZ 9350), ×2½. Locality SA-C-5, at 8–10 feet above base of Parker. (p. 790)

10—*Wimanella? orientalis* (Whitfield), 1884. Holotype ventral valve from Parker quarry (USNM Loc. 319g) (AMNH 208), ×2. (p. 803)

11—*Paterina labradorica swantonensis* (Walcott), 1890. Ventral (?) valve (MCZ 9352), ×2½. Locality M-NC-12, 170 feet above base of Parker. (p. 795)

12—Undetermined brachiopod. Unique ventral valve (MCZ 9358), ×8. Locality M-NW-1, lower 10 feet of Parker. (p. 803)

13—Undetermined gastropod. Unique steinkern (MCZ 5048), ×5½. Same location as *12*. (p. 804)

The frontal limb is upturned and bears a rim. The anterior facial sutures are straight but widely flaring so that a wide brim is formed.

The palpebral lobes are long and set off by a deep palpebral furrow; they originate opposite a point between the first and second pair of glabellar lobes, are arcuate, and die out opposite the occipital furrow.

The posterior limbs are narrow and strap-like and as wide as the occipital ring.

There seems to be little difference between this specimen and that figured by Rasetti (1948A, pl. 2, fig. 20) as *Prozacanthoides* sp. indet.

Ptychoparella adamsi (see **Billingsaspis adamsii**)

Ptychoparella billingsi (see **Billingsaspis adamsii**)

Ptychoparella georgiensis (see **Ptychoparella teucer**)

PTYCHOPARELLA? KINDLEI Resser, 1937
(Trilobite)

Ptychoparella kindlei RESSER, 1937, Jour. Paleontology, vol. 11, p. 50, pl. 8, figs. 40, 41. ——, LOCHMAN, 1947, Jour. Paleontology, vol. 21, p. 65.

There is nothing to add to the discussion and figures given by Resser. As Lochman points out, the holotype, and only known specimen, is so poorly preserved that correct generic assignment is not certain.

Holotype.—NMC 431a.

Type and only known locality.—USNM Loc. 319e, "1½ miles east of Swanton", probably near or at the base of the Parker slate.

Ptychoparella swantonensis (see **Billingsaspis walcotti**)

PTYCHOPARELLA TEUCER (Billings), 1861
(Trilobite)
Pl. 74, figs. 11–14

Conocephalites teucer BILLINGS, 1861, Canada Geol. Survey, Palaeozoic Fossils, vol. 1, pt. 1, p. 14, fig. 16.

Conocephalites Teucer, BILLINGS, 1862, Am. Jour. Sci., 2d ser., vol. 33, pp. 102, 104.

Conocephalites teucer BILLINGS, in Hitchcock and others, 1862, Geology of Vermont, vol. 2, p. 951, fig. 356. ——, LOGAN, 1863, Geology of Canada, fig. 295, p. 286 (no text).

Ptychoparia adamsi WALCOTT, 1886, (part), U. S. Geol. Survey Bull. 30, pp. 195–197, pl. 26, fig. 1c only. Figs. 1, 1a-b = *Billingsaspis adamsii*.

Ptychoparia teucer MILLER, 1889, North American Geology and Palaeontology, p. 565, Cincinnati, Ohio.

Ptychoparia adamsi WALCOTT, 1891 (part), U. S. Geol. Survey 10th Ann. Rept., pt. 1, p. 649, pl. 96, fig. 1c only. Figs. 1, 1a-b = *Billingsaspis adamsii*.

Anomocare Tucer MATTHEW, 1897, Royal Soc. Canada Proc. & Trans., 2d ser., vol. 3, pp. 198–199, pl. 4, fig. 8.

Ptychoparella teucer RESSER, 1937, Jour. Paleontology, vol. 11, p. 50, pl. 8, figs. 42, 43.

Ptychoparella georgiensis RESSER, 1937, op. cit., pp. 52–53, pl. 8, fig. 44.

Crassifimbra? georgiensis LOCHMAN, 1947, Jour. Paleontology, vol. 21, p. 66.

Unidentifiable LOCHMAN, 1947, op. cit., p. 66 (a reference to the holotype of *Conocephalites teucer*).

The holotype of this species is, as Lochman emphasized, very poorly preserved, but its condition is not exceptional for Parker fossils, and enough of it remains (as figured by Resser) to permit its recognition as a common species in the lower Parker slates.

The recovery of a complete specimen of *Ptychoparella teucer* as well as a study of the holotype of "*P. georgiensis*", which I believe to be the same species, permit a more complete description of the species than has heretofore been possible. Glabella truncato-conical, marked by three pairs of furrows, well incised in the holotype but faint in the figured entire specimen. Occipital furrow sinuous, deflected anteriorly in the center. Glabella about 0.4 as wide as the entire cranidium across center-points of eyes. Ocular ridges prominent. Cheeks confluent in front of glabella. Brim convex medially in a few specimens, with convexity accompanied by shallowing of the broad marginal furrow. Posterior limbs bluntly triangular, of about the same width as occipital ring. No occipital node or spine.

Thorax of at least 18 segments. Pleural furrows broad, rounded, running straight out to the end of the segment without deflection. Point of geniculation distant from the axial lobe by the width of that lobe. Pygidium small, transverse.

Examination of the type of "*Ptychoparella georgiensis*" (MCZ 2920) has convinced me that it is only a *P. teucer* which has suffered compression from the left rear toward the right front, squeezing the glabella up against the rim and obscuring the

marginal furrow entirely. A guttapercha squeeze of this specimen is figured stereoscopically for comparison with the other specimens illustrated.

Ptychoparella teucer, *Pagetides parkeri*, and *Kootenia marcoui* are the most characteristic fossils of the lower Parker slate.

Holotype.—NMC 431. Holotype of *P. georgiensis*, MCZ 2920.

Type locality.—"1½ miles east of Swanton in slates of the Potsdam group" (USNM Loc. 319e), probably in the base of the Parker.

Known stratigraphic range.—From USNM Loc. 319e at the base of the Parker to the Hall Farm (USNM Loc. 25a), about 450 feet above the base of the Parker. Notably abundant in the Kelly quarry slates 150–160 feet above the base of the Parker (Locality SA-C-1) (Shaw, 1954, pp. 1036, 1038, 1039, 1041, 1042).

Ptychoparella vermontensis (see **Billingsaspis adamsii**)

Ptychoparella vulcana (see **Billingsaspis adamsii**)

Ptychoparella walcotti (see **Billingsaspis walcotti**)

Ptychoparia adamsi (see **Billingsaspis adamsii, Periomma typicalis** and **Ptychoparella teucer**)

Ptychoparia arenosa (see **Perimetopus arenosus**)

Ptychoparia teucer (see **Antagmus typicalis** and **Ptychoparella teucer**)

Ptychoparia trilineata (see **Atops trilineata**)

Ptychoparia vulcanus (see **Antagmus simplex** and **Periomma typicalis**)

RUSTELLA EDSONI Walcott, 1905 (Brachiopod)

Rustella edsoni WALCOTT, 1905, U. S. Nat. Mus. Proc., vol. 28, pp. 11–12. ——, WALCOTT, 1912, U. S. Geol. Survey Mon. 51, pp. 327, 328, pl. 1, figs. 1, 1a-e. ——, SHIMER & SHROCK, 1944, Index Fossils of North America, p. 293, pl. 110, fig. 4, John Wiley, N. Y.

Rustella edsoni was erected for some specimens previously referred to *Kutorgina cingulata* but believed to differ from that genus and species in their greater simplicity of structure. Examination of specimens of both species from Vermont leads me to put forth the suggestion that *R. edsoni* and *K. cingulata* are the same species, with the former based on more or less compressed internal impressions from shale and the latter, on specimens retaining convexity, from limestone or calcareous sandstones. It is only fair to say, however, that *R. edsoni* is a rare species, never well-preserved, and it has been impossible to prove this hypothesis to anyone's satisfaction but my own. I have, therefore, listed *R. edsoni* separately.

Holotype.—USNM 51412a (Walcott, 1912, vol. 2, pl. 6).

Type locality.—Sandstone just above Parker quarry (USNM Loc. 25), 170–210 feet above the base of the Parker slate.

SALTERELLA PULCHELLA Billings, 1861 (Mollusk)

Salterella pulchella BILLINGS, 1861, Canada Geol. Survey, Palaeozoic Fossils, vol. 1, pt. 1, p. 18. ——, BILLINGS, 1862, Am. Jour. Sci., 2d ser., vol. 33, p. 104. ——, BILLINGS, in Hitchcock and others, 1862, Rept. Geology of Vermont, vol. 2, p. 955. ——, WALCOTT, 1886, U. S. Geol. Survey Bull. 30, pp. 144–145, pl. 7, fig. 7, 7a-c. ——, MILLER, 1889, North American Geology and Palaeontology, p. 520, Cincinnati, Ohio. ——, WALCOTT, 1891, U. S. Geol. Survey 10th Ann. Rept., pt. 1, p. 625, pl. 79, figs. 5, 5a-c. ——, WALCOTT, 1912, U. S. Geol. Survey Mon. 51, p. 188.

Walcott (1886) recorded this species sa ranging through the upper 500 feet of the "Red Sandrock" (=Dunham dolomite), and in 1912 he listed it from USNM Loc. 25a (the Hall Farm) about 450 feet above the base of the Parker. Billings also referred to the presence of this species in Vermont, but no specimens have been found in collections available to me.

Plesiotype.—GSC 410.

Cotypes.—GSC 407.

SALTERELLA RUGOSA Billings, 1861 (Mollusk)

Salterella rugosa BILLINGS, 1861, Canada Geol. Survey Palaeozoic Fossils, vol. 1, pt. 1, p. 17, fig. 22. ——, BILLINGS, 1862, Am. Jour. Sci., 2d ser., vol. 33, p. 104. ——, BILLINGS, in Hitchcock and others, 1862, Rept. Geology of Vermont, vol. 2, p. 954, text-fig. 362. ——, LOGAN, 1863, Geology of Canada, fig. 292, p. 285 (no text). ——, WALCOTT, 1886, U. S. Geol. Survey Bull. 30, pp. 145–146, pl. 13, fig. 2. ——, MILLER, 1889, North American Geology and Palaeontology, p. 520, fig. 942, Cincinnati, Ohio. ——, WALCOTT, 1891, U. S. Geol. Survey 10th Ann. Rept., pt. 1, p. 625, pl. 79, fig. 4.

Walcott (1886) simply stated that this species was present in the "Georgia formation" (=Parker slate), but he did not elaborate further, and his later lists (Walcott, 1912) did not include the species. Poorly preserved *Salterella* in the Gilman may belong to this species but it is by no means certain.

Holotype.—missing (W. A. Bell, letter, Sept. 9, 1952).

Paratypes.—GSC 408a.

Type locality.—Anse au Loup. Presence in northwestern Vermont not established.

SALTERELLA sp. indet.

Fragmentary *Salterella* have been found in the Gilman quartzite of the quarry on Aldis Hill in the northern part of the city of St. Albans, in association with macerated trilobite remains. The species is not identifiable but bears closest resemblance to *S. rugosa.*

The beds appear to lie about 100 feet below the Dunhan dolomite, although heavy cover precludes precise location of the Dunham-Gilman contact.

The specimens are in the MCZ and are unnumbered.

SCENELLA? VARIANS Walcott, 1886 (Gastropod)

Scenella? varians WALCOTT, 1886, U. S. Geol. Survey Bull. 30, p. 127, pl. 12, figs. 2, 2a.
Scenella varians MILLER, 1889, North American Geology and Palaeontology, p. 392, Cincinnati, Ohio.
Scenella? varians WALCOTT, 1891, U. S. Geol. Survey 10th Ann. Rept., pt. 1, p. 617, pl. 73, figs. 5, 5a.
Scenella varians WALCOTT, 1912, U. S. Geol. Survey Mon. 51, p. 188.

This species has been reported from USNM Loc. 26, somewhere in the Dunham, but no specimens of it have come to my attention.

Holotype.—USNM 15370 (?); never designated clearly.

Type locality.—Not designated.

Stratigraphic position.—USNM Loc. 26 somewhere in Dunham dolomite.

Solenopleura arenosa (see **Perimetopus arenosus**)

SWANTONIA ANTIQUATA (Billings), 1861 (Brachiopod)

Camerella antiquata BILLINGS, 1861, Canada Geol. Survey, Paleozoic Fossils, vol. 1, pt. 1, p. 10, text-fig. 13. ——, BILLINGS, 1862, Am. Jour. Sci. 2d ser., vol. 33, pp. 102, 104, 105. ——, BILLINGS, in Hitchcock and others, 1862, Rept. Geology Vermont, vol. 2, p. 949, text-fig. 353. ——, LOGAN, 1863, Geology of Canada, text-fig. 290, p. 284 (no text).——, WALCOTT, 1886, U. S. Geol. Survey Bull. 30, pp. 122–123, pl. 7, fig. 8. ——, MILLER, 1889, North American Geology and Palaeontology, p. 338, Cincinnati, Ohio. ——, WALCOTT, 1891, U. S. Geol. Survey 10th Ann. Rept., pt. 1, p. 613, pl. 72, fig. 3.
Camarella? antiquata HALL & CLARKE, 1894, Palaeontology New York, vol. 8, pt. 2, p. 220.
Protorhyncha? antiquata SCHUCHERT, 1897, U. S. Geol. Survey Bull. 87, p. 334.
Swantonia antiquata WALCOTT, 1905, U. S. Nat. Mus. Proc., vol. 28, no. 1395, pp. 296–297. ——, WALCOTT, 1912, U. S. Geol. Survey Mon. 51, p. 797, pl. 104, figs. 5, 5a-b) ——, SCHUCHERT & COOPER, 1932, Peabody Mus. Nat. History Yale. Univ. Mem., vol. 4, pt. 1, p. 159.

No specimens of this species have been found during the present survey. The type locality, described as "1½ miles east of Swanton" (USNM Loc. 319e) was not rediscovered, but it probably lay in the basal Parker. A specimen in slate in the Museum of Comparative Zoology seems to demonstrate the presence of the species in the Parker.

Holotype.—USNM 15363 (fide Walcott 1891).

Type and only known locality.—USNM Loc. 319e, "1½ miles east of Swanton."

Syntrophia billingsi (see **Huenella billingsi**)

TUZOIA VERMONTENSIS Resser & Howell, 1938 (Crustacean)

"A problematical organic marking" WALCOTT, 1891, U. S. Geol. Survey 10th Ann. Rept., pt. 1, pl. 59, fig. 1.
Medusa? sp. WALCOTT, 1912, U. S. Geol. Survey Mon. 51, p. 188.
Tuzoia vermontensis RESSER & HOWELL 1938, Geol. Soc. America Bull., vol. 49, p. 231, pl. 13, fig. 1.

The discussion and figures by Resser & Howell are adequate.

Holotype.—USNM 26728.

Type and only known locality.—Sandstones above Parker quarry slates (USNM

Loc. 25), 170–210 feet above the base of the Parker (fide Resser & Howell).

WIMANELLA? ORIENTALIS (Whitfield), 1884 (Brachiopod)
Pl. 76, fig. 10

Orthisina orientalis WHITFIELD, 1884, Am. Mus. Nat. History Bull., vol. 1, no. 5, p. 144, pl. 14, fig. 6. ——, WALCOTT, 1886, U. S. Geol. Survey Bull. 30, p. 120, pl. 7, fig. 6. ——, MILLER, 1889, North American Geology and Palaeontology, p. 360, Cincinnati, Ohio. ——, WALCOTT, 1891, U. S. Geol. Survey 10th Ann. Rept., pt. 1, p. 613, pl. 72, fig. 8.
Billingsella orientalis WALCOTT, 1905, U. S. Nat. Mus. Proc., vol. 28, no. 1395, pp. 239–240. ——, WALCOTT, 1912, U. S. Geol. Survey Mon. 51, p. 759, pl. 86, figs. 2, 2a-b.
Nisusia? orientalis SCHUCHERT & COOPER, 1932, Peabody Mus. Nat. History Yale Univ. Mem., vol. 4, pt. 1, p. 45.
Wimanella? orientalis SHAW, 1954, Geol. Soc. America Bull., vol. 65, pp. 1036, 1040, 1042.

Through the kindness of Dr. Otto Haas I have had the privilege of studying the holotype of *Orthisina orientalis*, the internal impression of a ventral valve, which is here illustrated for the first time photographically.

W.? orientalis is known only from the ventral valve, which is subquadrate, slightly longer than wide. The hinge-line is straight; interareas are large and orthocline. There is a rather deep pedicle pit but no individual muscle scars are recognizable. Neither are there any visible pallial markings. The ribbing is costellate, notably finer than that of any *Nisusia*.

A glance at the specimen is sufficient to show that it is not a *Nisusia* and the subquadrate shape and high orthocline interarea at once suggest reference to *Billingsella*, the generic assignment given by Walcott. But *O. orientalis* does not fit into *Billingsella* as it has been restricted by Schuchert & Cooper, because there is no visible trace of a xenidium (Cloud, 1942, p. 20). Therefore, the most suitable generic assignment that can be made on the basis of the single specimen now available is to *Wimanella* which is a billingselloid genus with open delthyrium.

Holotype.—AMNH 208.

Type locality.—Shales at Parker quarry (USNM Loc. 319g), about 150 feet above the base of the Parker slate.

Stratigraphic range.—Known certainly only at the type locality. Unconfirmed reports place the species at USNM Loc. 26, somewhere in the Dunham dolomite, and at USNM Loc. 25a (Hall Farm) about 450 feet above the base if the Parker (Shaw, 1954, pp. 1036, 1040, 1042).

ZACANTHOPSIS sp. indet. (Trilobite)
Pl. 74, figs. 5–8

Two cranidia of *Zacanthopsis* have been found at MN-W-1. Like most specimens from this locality they are internal impressions and do not provide sufficient basis for specific identification.

The glabella is parallel-sided, unmarked except for the occipital furrow. The occipital ring is triangular and was apparently produced rearward into a spine. Fixed cheeks rise to half the height of the glabella and are smooth. The palpebral lobes are destroyed but were apparently small. A deep marginal furrow passes in front of the glabella and sets off a sharply inclined rim. Posterior limbs are about equal in width to the occipital ring.

Measurement in millimeters (MCZ 5011 and 5030, respectively)—Total sagittal cranidial length, 6.9, 7.1; length of glabella, including occipital ring, 5.6, 5.7; glabellar length, minus occipital ring, 4.4, 4.6; maximum width of frontal limb, 7.0, 7.0; width of occipital ring, 2.8, 2.5; width of glabella opposite eye-centers, 2.5, 2.4; maximum glabellar width (anterior), 2.7, 2.7.

Plesiotypes.—MCZ 5011 (figured) and MCZ 5030.

Only known locality.—In weathered ocherous dolomite residues at M-NW-1, five to ten feet above the base of the Parker slate.

Undetermined brachiopod
Pl. 76, fig. 12

Undetermined crustacean (?) SHAW, 1954, Geol. Soc. America Bull., vol. 65, p. 1038.

Further study of the unique specimen previously referred to as a crustacean (?) has revealed that it is a ventral valve of a brachiopod. The valve is smooth and marked only by a sharp, crease-like sulcus. The hinge line is straight and slightly less than the greatest width of the valve. The margins are gently rounded. The interareas

are very minute and apsacline, forming an angle of about 70° with a plane passing through the hinge line and the anterior median point on the line of commissure. Preservation of the delthyrial area suggests the presence of a xenidium, but there can be no certainty on this point. Maximum original width (restored): 4.4 mm. at 1.9 mm. from the posterior margin. The hinge line is 3.9 mm. Length: 4.4 mm.

The shape of the valve suggests that the animal was a syntrophiacean and possibly a clarkellid, but it is impossible to make any unequivocal statements regarding its affinities. The xenidium, if present, would confuse the issue.

Figured specimen.—MCZ 9358.

Only known locality.—Locality M-NW-1 in the lower 10 feet of the Parker.

Undetermined gastropod
Pl. 76, fig. 13

Undetermined gastropod SHAW, 1954, Geol. Soc. America Bull., vol. 65, p. 1038.

A unique gastropod steinkern apparently represents a new genus and species, but the poor preservation makes it unwise to propose a name for it. The conch is apparently symmetrical, curving through an arc of about 125°. The aperture is widely flared and seems to have a slit like that found in *Chalarostrepsis* Knight, 1948, although not so long. The coarse sandstone of the matrix and filling has preserved no ornamentation. Antero-posterior length of aperture: approximately 7.5 mm. Maximum height at right angles to plane of aperture: 5.3 mm.

This specimen shows some characteristics that suggest that it may be ancestral to *Chalarostrepsis*, but it is clearly more primitive in its lesser degree of coiling.

Figured specimen.—MCZ 5048.

Only known locality.—Locality M-NW-1 in the lower 10 feet of the Parker.

FURTHER NOTES ON THREE LOWER CAMBRIAN FOSSIL LOCALITIES

In August, 1954, while my summary of the Lower and lower Middle Cambrian faunal succession was in press, I was able to visit northwestern Vermont and to make a special search for two Lower Cambrian localities that had not been located. While the search led to no positive results it did lead to some of a negative sort:

USNM Loc. 25a (The Hall Farm quarry; see Shaw, 1954, p. 1042): Through the courtesy of Mr. Carlton Donaldson, present owner of the Donaldson Farm, which incorporates the old Hall Farm, I was able to make an extended search of the old Hall Farm for rocks of the type preserved in the MCZ collections; the search proved fruitless. In discussing the problem with Mr. Donaldson, he recalled that several years ago dolomite and limestone was collected from the Hall Farm and crushed for road metal; some of the rock taken appears to have resembled the limestone of the old quarry, and it, thus, seems quite likely that the old quarry now lies strewn along some Vermont roads.

USNM Loc. 319e (Shaw, 1954, p. 1040): As pointed out in my previous discussion of this locality, described by Billings as "1½ miles east of Swanton," it must have been along the north bank of the Missisquoi River and probably lay beside the old river road between Swanton and Highgate Center. An examination of the river bank from the last exposure of the Dunham dolomite eastward to the end of the extant road showed no trace of bedrock, and a discussion with local residents elicited the information that in the middle 'twenties a severe flood deposited a layer of mud and silt about four feet deep over the whole area. Thus, Billings' fossil locality probably lies buried somewhere under river debris.

A short visit to Parker Cobble in June, 1954, in company with Miss Mary Gilman, yielded a small collection from the west side of the Cobble about 40 feet below the capping dolomite, or approximately 170 feet above the base of the Parker. This would be essentially equal to USNM Loc. 319m (Shaw, 1954, p. 1040), slightly above Locality M-NC-2U (loc. cit.) and essentially at the stratigraphic level of Locality M-NC-12 (loc. cit.). The collection was small but included fragments of pygidia of *Kootenia marcoui* (probably representing half a dozen individuals), *Periomma typicalis* (one cranidium) and *Pagetides parkeri* (one pygidium).

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NEW CHAZYAN ORTHOCONES

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ABSTRACT—Chazyan cephalopod faunas are briefly discussed; they mark the inception of most of the major divisions of nautiloids which persist into younger Ordovician beds. The greater part of Chazyan cephalopods remain undescribed; if other groups are in a similar state, it may explain in a large part the difficulties encountered in recognizing the Chazyan in many parts of North America. There is a highly distinctive but small cephalopod association in the lower Chazyan. Middle and upper Chazyan beds have many species in common; their recognition as distinct depositional units and as formations can be seriously questioned.

New forms described include *Baltoceras minor*, *Murrayoceras primum*, *Lamottoceras ruedemanni*, *L. nodosum*, *Nybyoceras cryptum*, *Nanno* sp., *Endoceras* sp., *Mesnaquaceras curviseptatum*, *Proteoceras pulchrum*, *Stereospyroceras champlainense*. The genera *Lamottoceras* (Endoceratidae), *Mesnaquaceras* (Michelinoceratidae) and *Proteoceras* and *Stereospyroceras* (Stereoplasmoceratidae) are new. Previously described forms revised are *Proteoceras perkinsi* (Ruedemann), *P. moniliforme* (Hall) and *Valcouroceras tenuiseptum* (Hall).

INTRODUCTION

IN THIS paper are assembled descriptions of some straight cephalopods from the Chazyan of the Champlain basin, which prove to be of more than ordinary interest. The endoceroid *Lamottoceras* is significant as the only form thus far found in America which is closely allied to *Kotoceras* of the Toufangian of Manchuria. A small but unique asociation of orthoconic cephalopods from the lower Chazyan, containing some genera not recognized in higher Chazyzn beds, is described. The new genus *Proteoceras* of the middle and upper Chazyan is remarkable in the structure of the cyrtochoanitic siphuncle of its early stages, while in later stages the siphuncle becomes so tubular that late portions alone would be identified as species of *Michelinoceras*. This genus and *Stereospyroceras* belong to a group of Ordovician cyrtochoanitic orthocones which the writer (in Flower & Kummel, 1950) regarded as the family Stereoplasmoceratidae. Miller & Youngquist (1949) and Teichert & Glenister (1953) have discussed similar forms which they have assigned to the Pseudorthoceratidae. An accompanying paper will discuss this problem more thoroughly. It will suffice to say here that the Stereoplasmoceratidae is regarded as a group of cyrtochoanitic cephalopods derived from the Michelinoceratidae, in or shortly prior to Chazyan time. The Pseudorthoceratidae are strongly homeomorphic with this family, but differ in the ontogeny of the siphuncle segments and show some important differences in cameral and siphonal deposits.

The Chazyan of the Champlain Valley contains a large and significant cephalopod assemblage. I knew it first from the monograph of Ruedemann (1906), notable as the only outstanding contribution to the study of nautiloids after the death of Hyatt and prior to the investigations of Foerste, which began in the 1920's. Having been much impressed with this fine work, I was the more amazed when, on my first meeting with Dr. Ruedemann, he urged me strongly to continue the study of the Chazyan cephalopods, saying that his own work was a mere beginning. The study of these forms has occupied my attention since 1933, and collections were built up whenever opportunity afforded. Descriptions of some 60 species were completed in 1940, but publication was largely delayed in the expectation of obtaining and studying more complete material. Though much supplementary material was collected in the six years I spent at the New York State Museum, it remained almost completely unworked, owing to the pressure of other duties, and restricted facilities for preparation and photography. Much of this material, including a good part of my earlier collections, remains at the New York State Museum unworked.

The Chazyan cephalopods were first brought together by Ruedemann (1906) in the classic work to which reference has already been made. There 21 species were

recognized, 16 of which were new. To these have been added *Meniscoceras coronense* (Flower, 1941), the Ascoceratida, comprising the new genera *Montyoceras*, *Hebetoceras* and *Ecdyceras*, (Flower, 1941a) the species of *Valcouroceras* (Flower, 1943), species of *Eorizoceras*, *Eotripteroceras*, *Graciloceras*, *Centrocyrtoceras* and *Trocholites* (Flower, 1943a), later species of *Kionoceras*, *Zitteloceras*, *Avilionella* and an additional *Valcouroceras* (Flower, 1952) and the new endoceroids of the gerera *Hudsonoceras*, *Allotrioceras* and *Mirabiloceras* (Flower, 1955). These works, with the present contribution, bring the number of described species up to 50; easily as many more await description.

The Chazyan cephalopods are important both faunally and phyletically. They mark the beginning of most of the stocks which are the important contributors to later Ordovician faunas. Further, they supply the only American Ordovician fauna thus far encountered in which internal structure is well preserved in extremely early growth stages. With the exception of some remarkable endoceroids regarded as offshoots of the Proterocameroceratidae of the Canadian assigned to the Proterocameroceratidae, Manchuroceratidae and the exclusively Chazyan Allotrioceratidae, and the coiled Trocholitidae, the connection between the Chazyan nautiloids and their Canadian ancestors is sufficiently remote to present many serious problems.

No genera pass the Canadian-Chazyan boundary. Post-Canadian species attributed to *Tarphyceras* belong actually to other genera; the Chazyan species *Tarphyceras champlainense* is the genotype of *Avilionella* Flower. This species is apparently the basis of the indication in the recent Ordovician correlation chart (Twenhofel et al., 1954), of *Tarphyceras* extending from upper Canadian into the Chazyan.

Of the nautiloid families of the Canadian which persist into the Chazyan there are only the Proterocameroceratidae, Manchuroceratidae, Trocholitidae, and doubtfully the Plectoceratidae, and the declining Baltoceratidae and Eothinoceratidae (= Cytocerinidae Flower). In contrast, eight of the families which include the greater number of the pre-Chazyan genera and species fail to survive the close of the Canadian. This number may be increased if it is found advisable to place the few Chazyan genera assigned to the Proterocameroceratidae in a distinct family, and if the Canadian forms assigned to the dominantly younger Plectoceratidae prove to belong instead to the Tarphyceratidae. In contrast to the six Canadian families which pass into Chazyan or younger beds, which may eventually be reduced to four, the Chazyan marks the inception of fourteen new families, the Endoceratidae and Allotrioceratidae of the Endoceratida, the beginning of the true actinoceroids, including the Chazyan Armenoceratidae and Golioceratidae, and the Asiatic Polydesmiidae. Probably the Ormoceratidae are not developed. The one described Chazyan form I now regard as being mislabeled and having come from post-Chazyan beds in the Champlain Valley, rather than from the true Chazyan. The Michelinoceratida appear, being represented by the Michelinoceratidae and Stereoplasmoceratidae, the Ascoceratida, represented by the archaic family Hebetoceratidae. Probably the dominantly European Clinoceratidae begins in the Chazyan. Among exogastric and coiled forms are the families Graciloceratidae, Oncoceratidae, Valcouroceratidae, Barrandeoceratidae. Possibly the European Lituitidae begins in beds of Chazyan age as Raymond (1916) believed.

The families and, indeed, quite a number of the genera which appear in the Chazyan, persist to the close of the Ordovician. There is no difficulty in connecting them with the stocks which dominate the Silurian faunas. In the Devonian the lines can be traced still further, though with the reservation that the origin of the Centroceratidae is open to question. In the later Paleozoic, most coiled stocks stem from the Rutoceratidae or Centroceratidae of the Devonian; the connection of the Liroceratidae with older coiled genera is still extremely problematical, but to these three main stocks, and the smaller Solenochilida of uncertain origin, belong apparently all of the post-Paleozoic coiled nautiloid stocks.

The base of the Chazyan marks a break of great magnitude, one so great that in considering the cephalopods, it is far simpler

to consider this as marking the boundary between the Canadian and Ordovician as distinct systems. Curiously, a change in the cephalopods of almost equal magnitude, occurs at the top of the Gasconade. Gasconade and older cephalopods constitute the Plectronoceratidae, Ellesmeroceratidae, and a beginning of the Protocycloceratidae. No other families are known there. The beds above yield the Proterocameroceratidae, Piloceratidae, Manchuroceratidae, Bathmoceratidae, Eothinoceratidae, Baltoceratidae, Thylacoceratidae, Cyclostomiceratidae, Protocycloceratidae, Bassleroceratidae, Tarphyceratidae, Trocholitidae and Piloceratidae, with three inadequately known genera assigned to the Ellesmeroceratidae. Certainly the evolutionary advances at the Gasconade-Roubidoux boundary indicate a great lapse of time. An even more profound break is indicated by the Canadian-Chazyan faunal changes. The range of the older nautiloid families, up to the Chazyan, has been indicated diagramatically by the writer (Flower, 1954, fig. 7).

In view of the large number of new forms which I have found among the Chazyan cephalopods, I cannot but wonder whether a similar close study founded upon careful collecting, might yield similar results among the other systematic groups comprising the Chazyan faunas. Of the other major groups, Raymond has studied the trilobites closely and the cystoids have attracted considerable attention, but little careful work has been done on the others, though Cooper has currently completed a study, now awaiting publication, on the brachiopods. For this reason, I would protest against the suggestion made in the recent Ordovician correlation chart (Twenhofel et al., 1954) that the term Chazyan might be abandoned as a major division of the Ordovician of North America, because the Chazyan represents a somewhat restricted and provincial fauna not clearly recognizable elsewhere. It is perfectly true that in many parts of North America, notably in the Appalachians, there are appalling difficulties in representing the Chazyan interval. However, I cannot but feel that this situation may be alleviated when the Chazyan faunas of the Champlain Valley have been subjected to more thorough study and collecting.

How much remains to be learned of the Chazyan faunas is perhaps exemplified by some correlations suggested by the cephalopods. Neuman (1951) has recently figured two supposed cross sections of *Cryptophragmus* from the St. Paul group of the central Appalachians. The significance of *Cryptophragmus* in these beds has been debated; it was contended on one hand that the presence of *Cryptophragmus* indicated a correlation with the Aylmer of Quebec and therefore with the Chazyan. It could as easily be contended that these *Cryptophragmus* could be younger, since there is a present gap in our knowledge of these fossils between the Aylmer *Cryptophragmus*, and its obvious descendant, *Beatricea*, in the Richmond. These particular specimens, however, proved not to be *Cryptophragmus* at all. One was a cross section of a siphuncle of *Meniscoceras*, a genus otherwise known only from the Crown Point beds of the Chazyan, and the other is very close to, possibly identical with, an endoceroid siphuncle as yet not thoroughly studied, from the Chazyan of Valcour Island. It is unlike any post-Chazyan endoceroid which has as yet come to my attention. I mention this not so much to correct the determination, as to supply a basis for my suggestion that further solutions to the correlation of these beds of probable Chazyan age, but with faunas unlike those of the Chazyan, may be found with further study of other faunal elements.

The Chazyan was divided by Brainerd and Seely (1891) into divisions A, B, and C. Cushing (1905) applied geographic names to these divisions, recognizing them as formations within the Chazyan group: the Day Point, Crown Point and Valcour limestones. In its type area there is little difficulty in distinguishing the Chazyan from older or younger units. Because of extensive cover, extensive block faulting, and the presence in a number of outcrops of anomalous lithological types and faunal assemblages, there has, however, been considerable difficulty in determining to which of these divisions certain beds and certain localities should be attributed. Notable examples are the beds exposed at the shore of Lake Champlain at Valcour, New York, and some of the fault blocks, notably on the southeast side, of Valcour Island.

As a result of my own observations, it

appears that the lower Chazyan, the Day Point limestone, retains its identity fairly well throughout most of the Champlain Valley, though I would concur with Raymond (1906) that the beds at Valcour, New York, which Ruedemann attributed to this interval are more probably middle Chazyan. Paradoxically, it was largely these exposures, of which a careful section was given by Ruedemann (1906), which Cushing had in mind in applying the name Day Point limestone to Brainerd and Seely's division A. Happily, this is not relevant, for as Kay pointed out (in conversation) Cushing merely applied his geographic name to division A of Brainerd and Seely; therefore the type section of A, west of Chazy, is the type section of the Day Point limestone, rather than the beds at Day Point.

There are some restricted outcrops attributable to the Crown Point and Valcour limestones which are peculiar to themselves both in lithology and many elements of their faunas, such as the two mentioned above. The massive dove grey limestones associated with algal reefs, and replete with cephalopods, trilobites and gastropods, essentially the *Glaphurus pustulatus* fauna of Raymond (1906), were formerly regarded as confined to the Valcour limestone. It is now evident that while this is true of many exposures, beds of identical lithology, and so far as my collecting has indicated, essentially identical faunas, may be found in beds which are clearly middle rather than upper Chazyan. Except for *Rostricellula plena*, normally plentiful in other facies, but occasionally found in these reefy massive limestones, there is very little to distinguish the Valcour from the Crown Point limestone faunally. My collecting has many times yielded species from one of these divisions which I had at first believed to be confined to the other. The apparent faunal differences seem to resolve themselves into a matter of differences in abundance of many of the species. I strongly suspect that further field work would reduce the apparent differences still further.

Neither the Crown Point nor the Valcour limestones seem to have either lithological or faunal characteristics on the basis of which they can be clearly separated in the Champlain Valley. It would seem, therefore, that unless further studies bring to light new evidence not now apparent, the validity of these units as distinct formations is open to very serious question, and that there is little point in attempting to apply geographic names to smaller stratigraphic and faciological divisions within the middle and upper Chazyan.

The Day Point limestone has yielded few cephalopods. The only notable association is that found in rubbly shaly limestones on South Hero Island, 1¼ miles southwest of South Hero, and north of Phelps Point. Here were found *Baltoceras minor*, *Murrayoceras primum*, *Mesnaquaceras curviseptatum* and three endoceroids, two figured here as "*Nanno*" sp., and *Endoceras* sp. Except for the endoceroids, which are the oldest of the true Endoceratidae I have encountered, and concerning whose specific and generic affinities there remains some doubt, the genera represented here have not been found in other parts of the Chazyan of the Champlain Valley, or, for that matter, Quebec or the Mingan Islands.

Other beds attributed to the lower Chazyan have yielded very few cephalopods. Beds on the southwest corner of Valcour Island with silicified brachiopods, contain a *Proteoceras* cf. *P. moniliforme*, but the single specimen was destroyed in attempting to collect it. The quarries in the limestones rich in cystid plates near Day Point and Valcour have yielded a fragment of an *Avilionella* and a few fragments of *Michelinoceras*.

The middle and upper Chazyan have as their commonest cephalopods the large endoceroids so difficult to identify, and the small annulated shells formerly included under *Spyroceras clintoni* (Hall). These species, which comprise the nucleus of the genus *Stereospyroceras*, actually constitute a number of distinct species varying widely in proportions, some showing late ontogenetic stages with the annuli suppressed the siphuncle becoming tubular, or both. *Lamottoceras*, *Endoceras*, "*Nanno*," *Gonioceras*, *Plectoceras*, *Avilionella*, *Valcouroceras*, *Michelinoceras*, *Proteoceras*, *Kionoceras*, *Sigmorthoceras*, *Centroonoceras* and *Ruedemannoceras* are common to the Crown Point and Valcour limestones, in many cases represented by the same species in both. Thus far *Meniscoceras* appears to be confined to the Crown Point beds of the southern end

of the Champlain Valley; *Nybyoceras* is uniformly rare, but more widely distributed in Crown Point beds. *Graciloceras*, *Eorizoceras*, *Eotripteroceras*, *Montyoceras*, *Hebetoceras*, *Centrocyrtoceras* and *Barrandeoceras* seem to be confined to the rich assemblages of the cephalopod facies of the Valcour limestone, but beds of this facies of definite Crown Point age have not been nearly as thoroughly collected; when they are, this list may well be reduced.

Mirabiloceras and *Hudsonoceras* are known only from single specimens from the supposed upper Chazyan of Valcour Island; *Allotrioceras*, from a single specimen from the Crown Point limestone. When the genera restricted to only one of these two divisions known from either single specimens, a single anomalous assemblage, or from the intensively collected reefy beds of Valcour age are discounted, the differences between the Crown Point and Valcour cephalopod faunas are not very significant.

ACKNOWLEDGMENTS

The type of *Oonoceras perkinsi* was loaned from the University of Vermont through the kindness of Dr. C. D. Doll. Of the remaining material, from my own collecting, *Lamottoceras* is in the New York State Museum; the remainder is from my earlier collections, to be deposited in the New Mexico Bureau of Mines. For assistance in some of the photography I am indebted to Mr. John Heller of the New York State Museum and Mr. Charles Trisuder of the New Mexico Institute of Mining and Technology. Many of the sections illustrated are opaque, and were photographed under water, which permits satisfactory enlargements approaching those of a thin section for the relatively low magnifications required by most cephalopod structures.

DESCRIPTIONS OF GENERA AND SPECIES

Family BALTOCERATIDAE

BALTOCERAS MINOR Flower, n. sp.

Pl. 80, figs. 5–6

This is a small slender orthoconic shell, cross section very slightly wider than high, with a very large ventral siphuncle. Septal necks short, supplemented by relatively thick connecting rings. Siphuncle without known organic deposits. Sutures are straight and transverse, the camerae are spaced four in a length of 10 mm. throughout the known part, which includes about 60 mm. of the phragmocone, in which the cross section ranges from 15 to 20 mm. in height with a width 1 to 1.5 mm. greater.

EXPLANATION OF PLATE 77

All except figure 1 are natural size

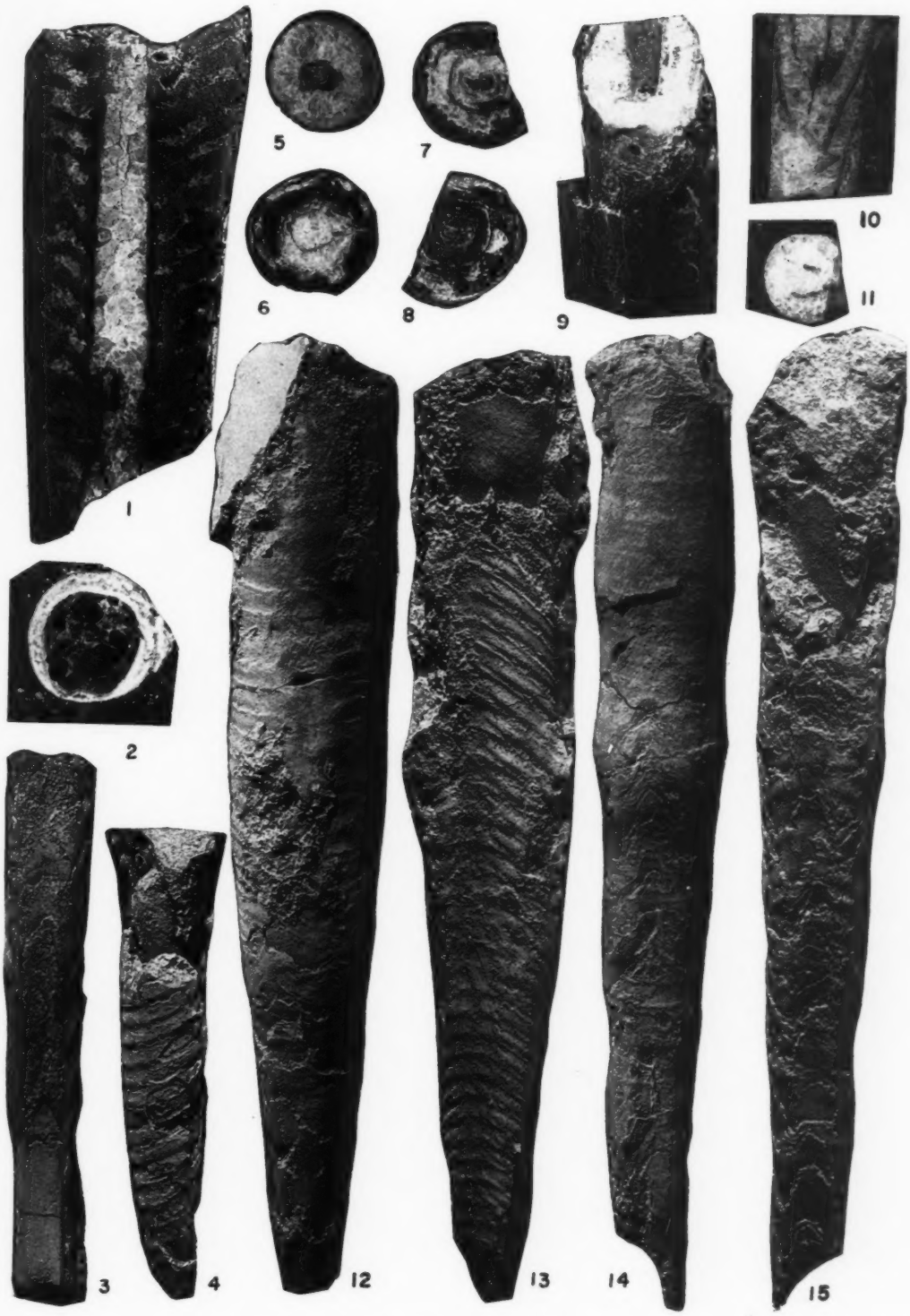
FIG. *1*—*Murrayoceras primum* Flower, n. sp. Horizontal longitudinal section from base of holotype ×2, ground from the dorsal side, showing siphuncle and cameral deposits. lower Chazyan, South Hero Island. See also pl. 79, fig. 1. (p. 811)

2—*Lamottoceras nodosum* Flower, n. sp. Transverse section of siphuncle across the endosiphocone. (p. 817)

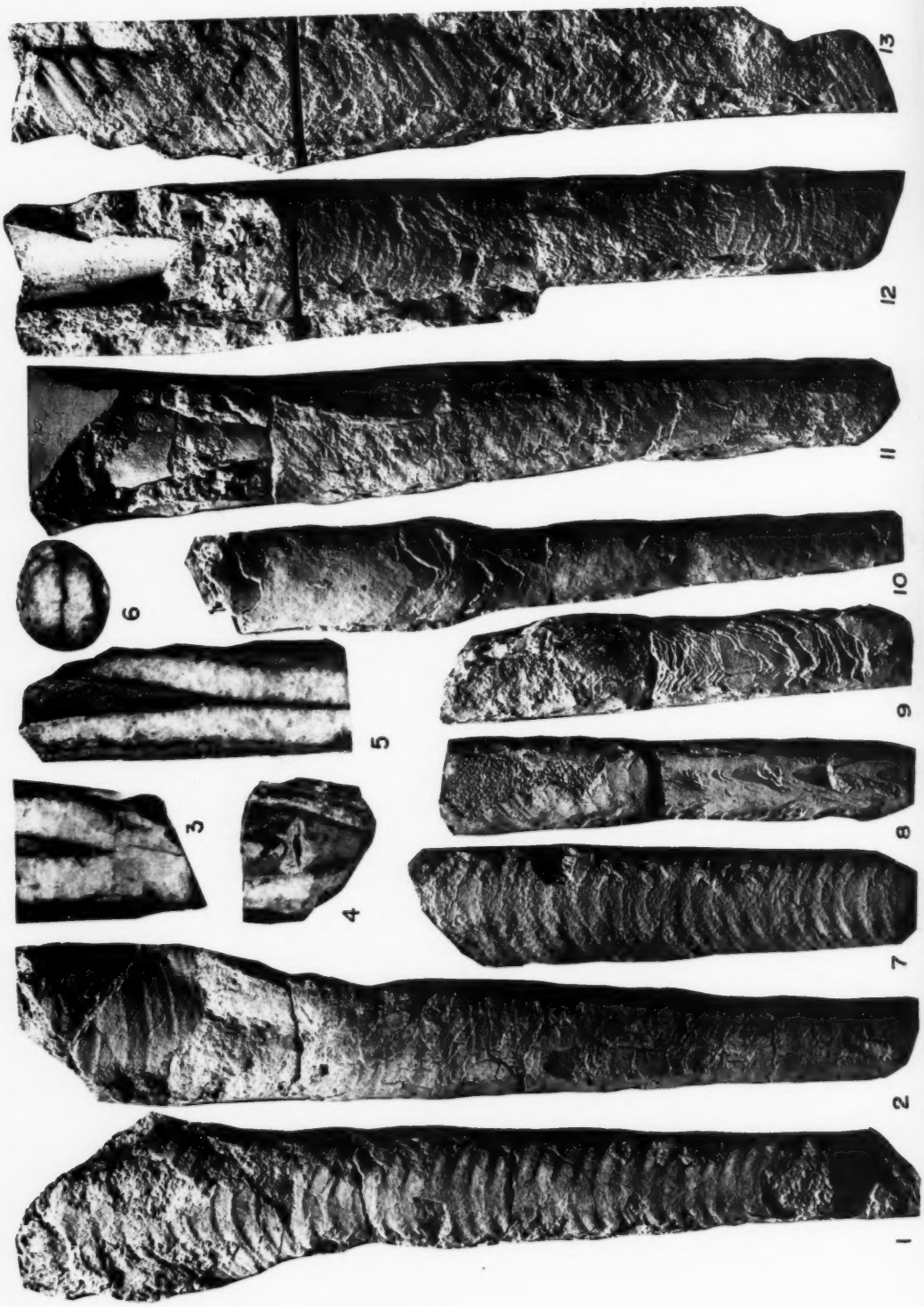
3–11—*Lamottoceras ruedemanni* Flower, n. sp. *3*, Portion of an exfoliated surface viewed from the ventral side, showing "saddle" caused by forward extension of endocones. Distal parts of endocones are removed near the base, producing a flat surface. *4*, Lateral view of a siphuncle close to the apical part of the shell. *5*, Cross section of adoral part of same specimen as Pl. 78, fig. 5 in longitudinal section. *6–8*, three successive cross sections of one of the very few specimens of siphuncles showing the endocones clearly. *9*, Adoral end of a broken siphuncle, looking obliquely down on the flattened surface of the ventral side of the endosiphocone from which the matrix has been removed. *10*, Section taken farther apicad from the same specimen, showing traces of endocones in longitudinal section. *11*, Cross section in typical state of preservation, showing endosiphotube and below it part of an endocone. Upper Chazyan, Isle La Motte. (p. 815)

12–13—*Lamottoceras ruedemanni* Flower, n. sp. A slightly crushed endosiphuncle, *12*, dorsal and *13*, ventral views. Fig. 12 shows apically exfoliation of an endocone surface, bearing faint longitudinal markings, due to the angularity of the cones in cross section. (p. 815)

14–15—*Lamottoceras nodosum* Flower, n. sp. Holotype, an endosiphuncle, *14*, Dorsal view, showing slight exfoliation and saddle of endocones. *15*, ventral view, showing ventral saddle in apical portion, but also septal markings. Upper Chazyan, Isle La Motte. (p. 817)



Flower, New Chazyan orthocones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Septal necks are short, but show some variation in length, being half the length of the segment in one specimen representing an early portion, but relatively very much shorter in a fragment representing a late growth stage with a height of 20 mm. The siphuncle often contains calcite, which appears to be inorganic in origin.

Discussion.—This small and seemingly nondescript species is of interest inasmuch as it is confined to the basal Chazyan, and is one of the very few specimens known from North America which seems to be typical of *Baltoceras*. The camerae are rather close, but the relatively long necks and very large ventral siphuncle are both characteristic of the genus.

This is a very generalized orthoconic species, common but always rather poorly preserved in the lower Chazyan of South Hero Island. Nothing at all similar to it has been found in the more abundant and much better preserved faunas of the middle and upper Chazy beds.

The species is based upon three syntypes in the collection of the writer, from the lower Chazyan of the Menasqua farm, South Hero Island.

MURRAYOCERAS PRIMUM Flower, n. sp.
Pl. 77, fig. 1; Pl. 79, fig. 1

Shell straight, very gently expanding, depressed in section. Sutures transverse and essentially straight; without the usual conspicuous ventral lobe. Septa only slightly curved, siphuncle large and tubular, ventral in the early stages, but removed from the venter by slightly more than its own diameter in the late growth stages. The holotype, the most complete specimen observed as to length of the phragmocone, has had the dorsum lost by weathering; the actual width is apparently more rapidly increased adorally, as the apical portion is weathered to a point ventrad of the point of greatest width of the shell. It is 185 mm long, expanding in its present stage from 12 mm. to 36 mm. in width; the estimated original width of the apical end is 15 mm. Cross section evidently orginally strongly depressed, height estimated at 22 mm. where the width is 30 mm. Sutures are straight, transverse, very closely spaced, with 8 camerae in a length equal to an adoral estimated shell width of 16 mm.; 10 at 22 mm., 15 at 30 mm.

The apical portion of the type, shown only in a horizontal longitudinal section at the level of the siphuncle, shows camerae containing episeptal and hyposeptal deposits. Episeptal deposits are concentrated near the shell wall; hyposeptal deposits lie close to the siphuncle, so that, where calcite replacement is pronounced, as is true in most specimens, the section presents an aspect of rather steeply inclined septa which are nearly straight. The large tubular siphuncle is filled with calcite, showing no

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EXPLANATION OF PLATE 78

All figures natural size

FIGS. *1–4*—*Lamottoceras ruedemanni* Flower, n. sp. *1*, Ventral, and *2*, dorsal views of a relatively complete endosiphuncle, slightly crushed dorsally. Note slight exfoliation of terminal parts of endocones in lower part of fig. 2. *3*, Section through base of an endosiphocone, same specimen as Pl. 77, fig. 3. *4*, Portion of broken endosiphocone, same specimen as Pl. 77, fig. 3. (p. 815)

5–6—*Lamottoceras* sp. Sections through endosiphuncle. *5*, Longitudinal section, showing tapering of endosiphocone. *6*, Cross section at base, showing two horizontal blades. (p. 815)

7–9—*Lamottoceras ruedemanni* *7*, Ventral view of siphuncle, see also Text-fig. 2D. *8*, Ventral view, *9*, lateral view with venter on left, of endosiphuncle with tips of cones partially exfoliated, showing their pattern, the endosones swinging forward laterally from the ventral to the dorsal saddle. (p. 815)

10—*Lamottoceras nodosum* Flower, n. sp. Endosiphuncle showing slightly earlier growth stage than that included in the holotype. (p. 817)

11–13—*Lamottoceras ruedemanni* Flower, n. sp. *11*, Holotype, ventral view, see also Text-fig. 2A. *12–13*, Dorsal and ventrolateral views of holotype; midventral region at right of fig. 13. All specimens from the upper Chazyan, Isle La Motte, Vermont. (p. 815)

organic structures. The siphuncle wall shows short rather obscure septal necks, thick dense connecting rings which are very faintly curved, so that the adapical half of each segment of the siphuncle is very faintly expanded within the camerae. Connecting rings show in some segments a differentiation of materials suggestive of the development of an eyelet near their tips, but, from opaque sections, at least, the differentiation is imperfect and cannot be seen in all segments. The connecting rings are thickened slightly at the region of the most convex part of the segment of the siphuncle; there is indication that their inner surfaces are imperfect, having been partially absorbed in the white calcite of the center of the siphuncle.

The siphuncle is large, 6 mm. in diameter, circular, and in contact with the ventral wall at the apical end of the type. At the adoral end it is 9 mm. in width and is separated from the venter by very nearly its own diameter.

Discussion.—This species is extremely abundant in beds of shaly limestone near the base of the Chazyan, and shortly above the contact with the upper Canadian Providence Island limestone. It is completely unknown in higher beds of the Chazyan. Although all specimens are somewhat distorted, showing a greater or lesser degree of crushing. which makes it difficult to estimate the exact proportions of the shell the structure indicates that it is the oldest species of *Murrayoceras* thus far found. It differs from previously known forms largely in the absence of a ventral lobe of the sutures, which is a conspicuous feature in *M. murrayi* (Billings) the genotype. In *M. multicameratum* (Emmons) of the Lowville limestone, the ventral lobe is present, though broader and less sharply set off from the remainder of the suture, so that the sutures are essentially straight and slightly oblique in a lateral view of the shell. In *M. carletonense* the sutures are also essentially oblique on the sides, and describe a broad low lobe over the entire ventral surface. The siphuncles are tubular in outline in *M. carletonense* and *M. multicameratum*, and the connecting rings appear, from our present material, to be thin and homogeneous in structure. In *M. murrayi* there is a slight suggestion of the faint expansion of the segments in the camerae shown by *M. primum*, but the connecting ring is again thin and apparently homogeneous. *M. noveboracense* Flower of the Amsterdam limestone from Chazy, New York, has a much larger siphuncle in proportion to the shell, its segments are even more nummuloidal than in the present form, and the septa are straighter in horizontal section and more steeply inclined from the shell wall to the siphuncle.

Holotype.—Collection of the writer.

Occurrence.—From the lower layers of the Chazyan, a rubbly and slightly shaly limestone, one and one fourth miles southwest of the town of South Hero, from the lower part of the ridges exposed in the fields just west of the main road leading from South Hero southwest toward the Champlain shore east of Phelps Point, South Hero Island, Vermont.

Family ENDOCERATIDAE
NANNO n. sp.
Pl. 81, figs. 6–7

A single fragmentary early portion of an endoceroid of the *Nanno* type was found in the basal Chazyan of South Hero Island. The shell is a portion of a phragmocone 82 mm. long. The extreme tip is missing, though the lost interval is probably not over 4 mm. in length. Shell and siphuncle expand conically to a height of 17 mm. in the basal extant 25 mm. In the succeeding 12 mm. three camerae develop, causing the siphuncle to contract to a tube 10 mm. high, while the shell height increases, now more gently, to 19 mm. In the remaining length of the specimen, 40 mm., the shell increases to a height of 26 mm., the siphuncle to 13 mm. The camerae vary erratically in depth, measuring 5, 4, 7, 5, 5, 5, 4 and 4 mm. respectively. The cross section is poorly shown, but the height was evidently greater than the width at the adoral end of the fragment.

The apical 15 mm. of the siphuncle is filled with endocone material. The last cone extends forward to the ninth camera, a length of 60 mm. from the tip of the endocone. The siphuncle wall is holochoanitic and similar to that of *Nanno noveboracum* Ruedemann (see Flower, 1941).

Discussion.—It is of particular interest to note that this specimen is the oldest representative so far known of the type of early stage of endoceroids to which the generic name *Nanno* has been given. The specimen was fragmentary, so much so that it was embedded in plaster before being sectioned. The plane of the section is slightly oblique to the axis of the shell so that one side (Pl. 81, fig. 6) attains the center apically, but passes obliquely through the siphuncle adorally, making the siphuncle seem relatively small. This impression is corrected by illustrating the adoral part of the opposite side (Pl. 81, fig. 7), which attains the center of the siphuncle.

It has seemed wisest not to attach a specific name to this fragment. Like other "species" of *Nanno* it represents the early stages of the same shells which, when known from later portions, are identified as species of *Endoceras* or, sometimes, allied genera of the Endoceratidae. It is quite evident that the present specimen represents a species quite distinct from *Nanno noveboracum* of the upper Chazyan, a form which I regard as the early portion of "*Vaginoceras*" *oppletum* Ruedemann. It is felt that the naming of this fragment should be delayed pending the discovery and study of more material. The same beds which yielded *Nanno* sp., yielded also a fragment of a later stage of an endoceroid, about a foot and a half long, and about four inches in diameter at its basal end. Without intermediate stages, it is impossible to say whether the two are conspecific, though it seems highly probable that they might be. *Nanno* sp. shows some indication that the endocone extends forward farther on the dorsal than on the ventral side of the siphuncle. It is evident that the cross section of the endocone is, however, not markedly specialized after the manner of *Meniscoceras* or *Hudsonoceras*, but rather departs slightly if at all from being circular, as is usually the case in the true Endoceratidae. A third apical portion of an endoceroid of the *Nanno* type, of much larger dimensions than either this form or *N. noveboracum*, was found in the Chazyan at Valcour, New York. The Crown Point section has yielded also an endosiphuncle tapering gently to very small dimensions, which clearly could not have had the siphuncle expanded in the apical portion. The cones are nearly circular, regular, the tube central, and the endosiphuncle in general exhibits the simplicity associated with the true Endoceratidae, rather than the complex structure of the derived Proterocameroceratidae which have been found thus far in beds of Chazyan age.

The figured specimen, in the collection of the writer, is from the lowermost Chazyan associated with *Baltoceras minor* and *Mesnaquaceras curviseptatum*, on South Hero Island.

Endoceras sp.
Pl. 80, fig. 7

Among the straight slender shells of the rubbly beds of the lower Chazyan most of which belong to *Baltoceras minor*, is one shell with the camerae more closely spaced than the rest, apparently holochoanitic septal necks, and a siphuncle filled with calcite in the adoral end of which is a faint but unmistakable endocone. This fragment, 47 mm. long, has a shell expanding in that length from 16 to 18 mm. in height; the siphuncle is ventral, circular in cross section, and increases from 6.5 to 8.0 mm. in height. This specimen is worthy of note in that the siphuncle and shell are small and slender down to dimensions far smaller than those of the associated *Nanno* sp. It is indicative of the presence of a second species of endoceroid in the basal beds of the Chazyan. From the extant fragment it is impossible to say whether the very apex had a siphuncular expansion of the *Nanno* type; as yet no other type of apical end has been found in the Chazyan. If so, it is one of smaller dimensions than that of any previously known Chazyan species, and is smaller than typical *Nanno aulema* of the Platteville beds.

The figured specimen from the lower Chazyan of South Hero Island, is in the collection of the writer.

Genus LAMOTTOCERAS Flower, n. gen.
Genotype: *Lamottoceras ruedemanni* Flower, n. sp.

This genus is as yet known definitely only from a series of isolated endosiphuncles. Septal markings on the exterior are oblique, sloping forward on the side regarded as ven-

tral. Exfoliation, particularly pronounced in apical portions of siphuncles, presents a surface on the specimens which is caused by the peripheral part of the endocones. They slope forward into long tongue-like processes on the venter, the sides steep, and terminating in a pair of acute lobes. From there the margins swing forward toward the dorsal side in a sinuate manner, but again swing forward into a second long tongue-like process on the middorsal region. Cross sections through the endosiphocone show it to be subquadrangular in cross section, strongly flattened or even slightly concave on the ventral side, more curved laterally than dorsally, with a definite dorsal flattening resulting in the characteristic quadrate form of the speiss when it is seen, and the cross sections made of it. The cones terminate in a centrally located tube.

Discussion.—The remarkable endosiphuncles upon which this genus is based are from a single concentration on Isle La Motte. The association is a thanatocoenose, containing two obviously distinct species. Both are represented by only endosiphuncles, washed together after shell wall, phragmocone and the original siphuncle wall had evidently been destroyed by wave action. The quadrate cross section of the endocones and their remarkable peripheral pattern, particularly their extreme extension forward on the middorsal and midventral regions, are completely different from any endoceroids previously noted. The only endosiphuncles recorded which even suggest the present forms are those described by Kobayashi as species of *Kotoceras* from the Toufangian of Manchuria. Indeed, one species, *Kotoceras cyclindricum*, shows the same development of broad annuli exhibited by *Lamottoceras nodosum*. The endosiphuncles lack any indication of the dorsal and ventral processes of *Lamottoceras*, and the endosiphocone is not quadrangular in cross section, but more nearly semicircular. The cross sections figured by Kobayashi (1934) show the spiculum flattened on the venter, thinning laterally, and much thinner dorsally than laterally, an unusual feature. Further, *Kotoceras* has cones terminating in a tube which is not central, but lies close to the dorsal wall of the siphuncle.

Kotoceras was originally differentiated from other endoceroids by the marginal siphuncle, regarded as in contact with the ventral wall of the shell. This feature seems to be a rather dubious basis for generic distinction; my experience would indicate that it may vary among species otherwise similar structurally, and on this basis alone species with such different endosiphuncles as to be obviously unrelated, might be placed together. However, the genus appears to be a valid one on the basis of the features of the endosiphuncle, and the species thus far included in it appear to be closely related and

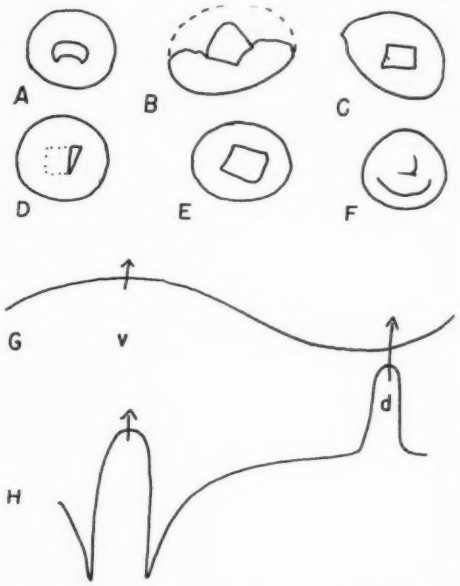

FIG. 1.—Features of endosiphuncle of *Lamottoceras ruedemanni*. A–F. Cross sections. A. Cross section showing typical section of endosiphocone. from specimen shown on Pl. 78, fig. 11. B. Restoration of partly exfoliated specimen showing strongly quadrate endosiphocone, Pl. 78, figs. 12–13. C. Section showing cone with strongly angled corners, from Pl. 77, figs. 12–13. D. Section preserving only part of endocone, having an apparently triangular section, Pl. 78, fig. 7. E. Apparent oblique cross section of endocone, from distortion, Pl. 77, fig. 4. F. Anomalous pattern complicated by recrystallization, from Pl. 77, fig. 9. G–H. Similarly oriented projections of (G) Septal markings on exterior of siphuncle, (H) "Suture pattern" due to termination of tips of endocones, with "sutures" swinging forward on sides from venter to dorsum, and extremely prolonged "saddles" on both middorsal and mid-ventral regions.

properly considered as congeneric. The siphuncle wall of *Kotoceras* possesses holochoanitic septal necks (Kobayashi 1934, confirmed, fide litt., 1954) and is probably to be referred to the Endoceratidae. A specimen retaining a phragmocone containing a siphuncle which seems to have the pattern of *Lamottoceras* has also holochoanitic necks. It retains only the extreme adoral part of the last endocones, and therefore the evidence it supplies is not to be regarded as absolutely conclusive. It could however, be an adoral part of the shell of *Lamottoceras ruedemanni*, very possibly of *L. nodosum* or even an undescribed species. The probability that it represents another genus is remote. The dubious evidence supplied by this specimen, coupled with the known holochoanitic nature of the similar genus *Kotoceras* (confirmed, Kobayashi, fide litt., 1954) are the basis of the tentative assignment of this new genus to the family Endoceratidae, though it must be emphasized that more complete material is badly needed to test this supposition further.

LAMOTTOCERAS RUEDEMANNI Flower, n. sp.
Pl. 77, figs. 3–13; Pl. 78, figs. 1–9, 11–13

This species is recognized by the relatively uniform rate of expansion of the siphuncle, in contrast to which the only other species of the genus, described below, has a siphuncle which is rhythmically expanded into faint nodes. Typical specimens of *L. ruedemanni* show an apparent rapid expansion of the early part of the siphuncle, which is purely adventitious, and is the result of the tendency toward the exfoliation of the outer part of the endocones near the apical end of the siphuncle. Such specimens may actually appear breviconic in the initial portion, but great variability is exhibited.

Junction of the septa with the outside of the siphuncle produces oblique ridges, which swing apicad on the dorsum, forming broad round lobes, and higher narrower saddles on the venter. Usually six sutures occur in a length of the siphuncle equal to the adoral width, though variations from five to seven have been noted. The siphuncle expands gently, increasing in the holotype (Pl. 78, fig. 11) from 12 and 13 mm. to 22 and 24 mm. in a length of 120 mm. Elsewhere, (Pl. 77, figs. 12–13) the rate of enlargement may be apparently greater at the apex, due to slight exfoliation, mainly, in this case, on the dorsal and lateral areas, for the ventral surface, which retains impressions of the sutures, is mainly intact. In general, the rate of expansion may be modified in passing from an apical area where slight exfoliation has occurred, to an adoral region where the outside of the siphuncle is intact.

Discussion.—The anomalies of preservation and possible variable features within the species, are best shown by a discussion of the individual specimens which are illustrated.

The specimen which is selected as the holotype (Pl. 78, fig. 11) is illustrated here with the venter just left of the center, so as to expose the exfoliated surface of the endosiphocone, which is here rounded. Just to the left, as shown in the cross section exposed by a plainly marked break, the ventral side of the cone is flattened and slightly concave; the dorsum is also broad and flattened, but not sharply set off from the lateral regions (Text-fig. 1A). Further apicad, the markings of the septa are complicated and sometimes confused by the rather irregular lamellate markings caused by exfoliation of the marginal parts of the endocones. In the apical part of this specimen the coarse crystalline white calcite fails to preserve the central endosiphocoleon or the endosiphoblades.

A second specimen (Pl. 78, figs. 12–13) is shown in both dorsal and lateral views, showing well the oblique course of the septal markings, which are preserved over an unusual distance of the specimen. The lateral view shows, in the lower half of the specimen, faint lamellar markings of the exfoliated endocones. The endosiphocone, which is removed in the portion figured, is definitely flattened ventrally, high arched the dorsum rounded and faintly narrowed (Text-fig. 1B) which is probably the result of distortion, for the ventral side of the siphuncle, not illustrated, is slightly crushed here. The section taken farther apicad fails to show any significant structures; the remainder of the siphuncle is filled with coarse white calcite which fails to retain significant internal structures.

Another relatively complete specimen,

slightly crushed adorally (Pl. 77, figs. 12–13), shows in ventral view part of the surface of the endosiphocone adorally, and the ventral impressions of the septa, which here form a rather complex pattern which cannot be interpreted with certainty without knowledge of the siphuncle wall. On the dorsal side, the septal markings are simple and fainter. At the adoral end a slight middorsal concavity results from the exfoliation of the dorsal saddle of the endocones. The surfaces of two endocones are shown here where, due to exfoliation, the septal markings are lost. Here also, exfoliation has produced the false appearance of a siphuncle which is rapidly expanding in the early portion, and more slender adorally. At the break, orad of the center, the endosiphocone is seen in cross section. Again, it is slightly irregular, possibly as the result of slight crushing of the specimen, but is closer to the typical quadrate pattern than was the previous specimen (Text-fig. 1C).

Another essentially complete siphuncle is shown in Pl. 78, figs. 1–2, again crushed adorally. The ventral crests of the sutural markings are slightly less prominent, simpler, and the whole sutural pattern is slightly less oblique. The endosiphocone is observable at the adoral end, but was not sectioned since it was obviously distorted by crushing. Pl. 78, fig. 2, shows the dorsal side, slightly tilted, the middorsal region to the left of the center. Adapically, the lamellate exfoliated margins of the endocones can be seen sloping orad toward the middorsal region to the left. Again, the interior of the siphuncle is filled with coarse calcite preserving none of the internal features.

On Pl. 78, fig. 7, is shown the unusually clear ventral side of a portion of another specimen, showing an appearance of the ventral sutures intermediate between those of Pl. 77, fig. 13, and the simpler condition of Pl. 78, fig. 2. The poorly preserved adoral part is not figured. The endocone is apparently triangular (Text-fig. 1D) but only the one side of it is preserved.

A small slender portion of a siphuncle showing advanced exfoliation, and the characteristic resulting pattern is shown in ventral view in Pl. 78, fig. 8, and in lateral view in fig. 9, with the venter on the left. Another case of exfoliation is shown in Pl. 77, fig. 3, where the ventral tongue-like processes are lost in the apical part, showing a faintly concave surface. Such specimens, which are not uncommon, are deeply exfoliated and cause the siphuncles to assume a quadrate cross section which was never true of their real outer surfaces.

Among our material there are no specimens which can be recognized as representing apical ends of cephalopods. One specimen suggests a portion near the apex. This is a fragment 70 mm. long (Pl. 77, fig. 4) with a strongly quadrate endosiphocone at the adoral end, which is, however, placed with one angle at the apparent ventral side (Text-fig. 1E). The siphuncle, 12 mm. in diameter at the lowest point at which it is complete, seems to have a fusiform outline, suggestive of a blunt apex as in the form-genus *Suecoceras*. However, we also have nondescript tubular very slender siphuncles as small as 8 mm. in diameter, usually without internal or external features. Possibly they are a distinct species, and perhaps even a distinct genus which occurs in the same association with *Lamottoceras*.

Internal structure is generally poor. The endosiphocone is well shown, the outer part of the siphuncle preserved, for some reason, the margins of the endocones, particularly in apical portions, are characteristically exfoliated; but usually the center of the main part of the siphuncle is filled with coarsely crystalline white calcite failing to preserve the endocones, the endosiphoblades, and frequently failing to preserve even the endosiphotube or coleon. Pl. 77, fig. 9, shows the adoral end of one such specimen, looking down upon a portion from which the endosiphocone has been removed. The grey band in the center represents the impression of its flattened ventral surface. The cross section at the base, (Text-fig. 1F) shows an incomplete curved band, evidently part of an endocone, a small subcentral dark spot representing the endosiphocoleon and portions of two dark bands arising from it but disappearing before they attain the margin of the siphuncle. A longitudinal section taken just apicad of this point (Pl. 77, fig. 10) confirms the interpretation of the curved band as a section

through an endocone. It is rare to find any trace of endocones within the main mass of the siphuncle in this material.

Variations in preservation are again shown by three sections from a single specimen shown on Pl. 77, figs. 6–8. Here, at the adoral end (Text-fig. 6) is seen a section through a quadrate endocone, with the remainder of the structure obscure. Two sections further apicad (Text-figs. 7–8) show numerous endocones. The specimen terminates just beyond the last section, and apparently the preservation of the endocones is here due to the penetration of carbonaceous material from the matrix at the broken end. Another quadrate cross section is shown in Pl. 77, fig. 5. Farther apicad (Pl. 78, fig. 3) is seen the termination of the endosiphocone in longitudinal section, and traces of the endosiphotube, here somewhat displaced and represented by a thin black line. Another longitudinal section through an endosiphotube (Pl. 78, fig. 5) terminates in a region showing in cross section (Pl. 78, fig. 6,) a transverse tube, an endosiphocoleon, connected to the edge of the siphuncle by two lateral blades. Here also is shown the grey color of the outer part of the siphuncle, observed in many cross sections; this is the portion along which the endocones may be exfoliated; nearer the center they are lost and there is only coarse crystalline white calcite. Many cross sections show as little as that in Pl. 77, fig. 11, or nothing at all. The present material contains some specimens, rather poorly preserved, indicating variation in the number and arrangement of the endosiphoblades; but they are not complete enough to show conclusively that they are conspecific with our other specimens. One shows two lateral blades, bifurcating as they approach the lateral margins, while another section shows three blades arranged in an irregular pattern. It is not yet evident what the normal pattern of the endosiphoblades was, nor whether it may have changed from the early to the late stages. Abundant material indicates that its variation is here evidently more apparent than real, being greatly complicated by loss and modification as the result of recrystallization of the interior of the siphuncle.

We have, of this species, about seventy specimens ranging from a few specimens 140 mm. long to small scraps. All of the material is from a single locality.

Types.—The holotype and paratypes, collected by the writer, are to be deposited in the New York State Museum.

Occurrence.—From the lower part of the Valcour limestone, on Isle La Motte, on a small knoll just east of Jordan Point.

LAMOTTOCERAS NODOSUM Flower, n. sp.
Pl. 77, figs. 2, 14–15; Pl. 78, fig. 10

In association with the preceding species there are some siphuncles which are conspicuously different in their habit of growth, for they expand at regularly rhythmic intervals giving the siphuncle a nodose appearance quite unlike that of the regularly expanding *L. ruedemanni*. Our material contains but four such specimens; doubtless there are more which are represented by siphuncles which do not show good surfaces and which have therefore been retained in *L. ruedemanni*. The two species exhibit no essential differences in internal structure. *L. nodosum* does show an additional difference in that the septa are somewhat more closely spaced in proportion to the diameter of the siphuncle.

The holotype (Pl. 77, figs. 14–15) a portion of a siphuncle 140 mm. long, increases from 12 and 12 mm. near its base to 20 and 20 mm. near the adoral end. As can be seen from the illustration, its expansion is irregular, areas of great expansion being spaced with their centers at intervals of between 20 mm. and 30 mm. apart. Eight to nine septa occur in a length equal to the adoral diameter of the siphuncle. In the adapical part, the exfoliation of the endocones shows the typical pattern, producing long tongue-like crests on dorsum and venter, connected by strongly oblique lines, sloping forward from venter to dorsum, on the sides. The endosiphocone is depressed, quadrangular, the ventral side concave and sharply set off from the sides; the dorsal surface meets the sides in strongly curved but not angular regions. There is a trace at the apex of two apparent endosiphoblades on one lateral side; the remainder of the pattern has been destroyed by recrystalliza-

tion. A second smaller specimen (Pl. 78, fig. 10) shows again the nodose mode of expansion of the species, but indicates that the siphuncle was more regularly expanding in the earlier stages. The internal structure is lost in this specimen.

A cross section through an endosiphocone (Pl. 77, fig. 2) shows the deposit thicker on the dorsum than on the venter, as is to be expected, for the endocones show, from their pattern on exfoliated surfaces, that they slope forward from venter to dorsum. The flattening of the middorsal region is vestigial; that on the thinner ventral side, however, is pronounced. The remainder of this specimen, again exemplifying exfoliation of the marginal part of the endocones near the apex, is not figured.

Discussion.—The remarkable form of the siphuncle will characterize this species. Only one other cephalopod with such a siphuncle has been described; this is an endoceroid, the endocone pattern of which is unknown, and consequently its generic position is uncertain. It is *Kotoceras cylindricum* Kobayashi (1934, pl. 10, fig. 6, pl. 12, fig. 8). *Kotoceras* is not a very well defined genus, being described as distinct from other endoceroids because the siphuncle is marginal. Possibly some of these forms are related to our present species, for Kobayashi described the endocones as flattened on the ventral side, but does not note their form as quadrate, nor does he report anything similar to the remarkable course of the margins of the endocones in their remarkable forward prolongations on dorsum and venter. Further, he reports the siphuncles as containing endocones terminating near the dorsal wall of the siphuncle, which is not true of our material.

The locality, horizon and deposition of types is the same as for the preceding species.

Family Armenoceratidae

Nybyoceras cryptum Flower, n. sp.

Pl. 79, figs. 2–3, 5–6; Pl. 81 figs. 3–4

Shell small, the three known specimens representing probably complete phragmocones which attained at the most a length of 35 mm., beginning with a broadly rounded first septum, at which the shell attains a width of about 16 mm. and a height of 12 mm., the shell enlarging gradually for the remainder of the length and attaining a known maximum width of 20 mm. The camerae decrease slightly in length as they are traced adorally, and the siphuncle, broadly expanded in the first camerae, becomes rapidly narrower. The shell was evidently only a very small one and from our evidence, never developed more than the very short phragmocones shown by our three specimens; nothing else has been found in the entire Chazyan remotely resembling this form, which could possibly be construed as representing later stages of its phragmocone.

The holotype (Pl. 79, figs. 5–6) as figured represents two halves of a specimen cut nearly horizontally through its longitudina

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Explanation of Plate 79

Fig. *1*—*Murrayoceras primum* Flower, n. sp., Weathered dorsal surface of holotype, ×1, see Pl. 77, fig. 1 for section from apical part, not included in the present photograph. Lower Chazyan, South Hero Island, Vermont. See also Pl. 77, fig. 1. (p. 811)

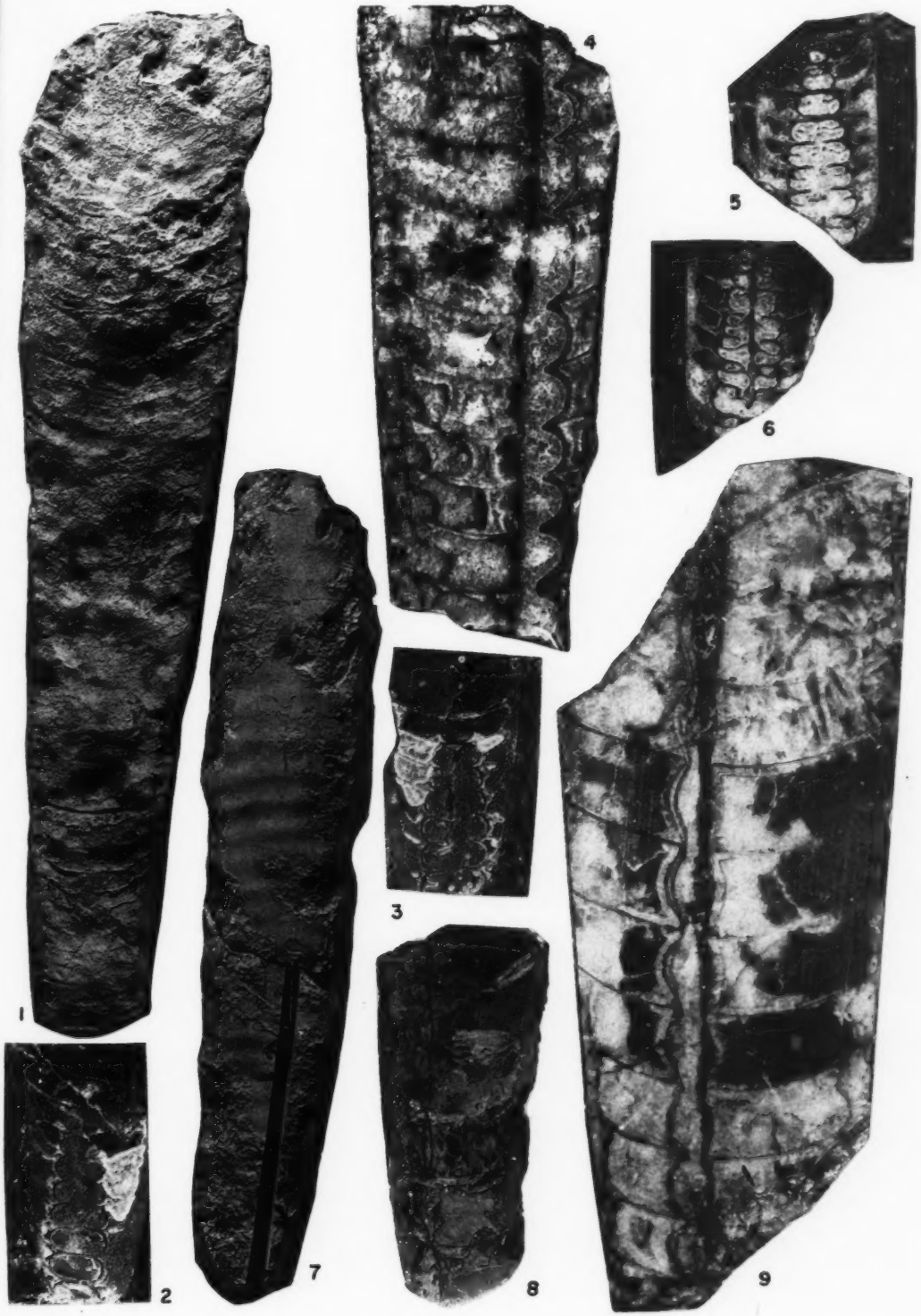
2–3—*Nybyoceras cryptum* Flower, n. sp. Paratype, ×1. Two halves of a slightly oblique longitudinal section; side nearer venter is on left of fig. 2; right of fig. 3. Middle Chazy, Vergennes, Vermont. (p. 818)

4—*Proteoceras* cf. *P. moniliforme* (Hall), Vertical section, about ×2.25. See also Pl. 81, fig. 2. Upper Chazy limestone, Little Monty Bay. (p. 826)

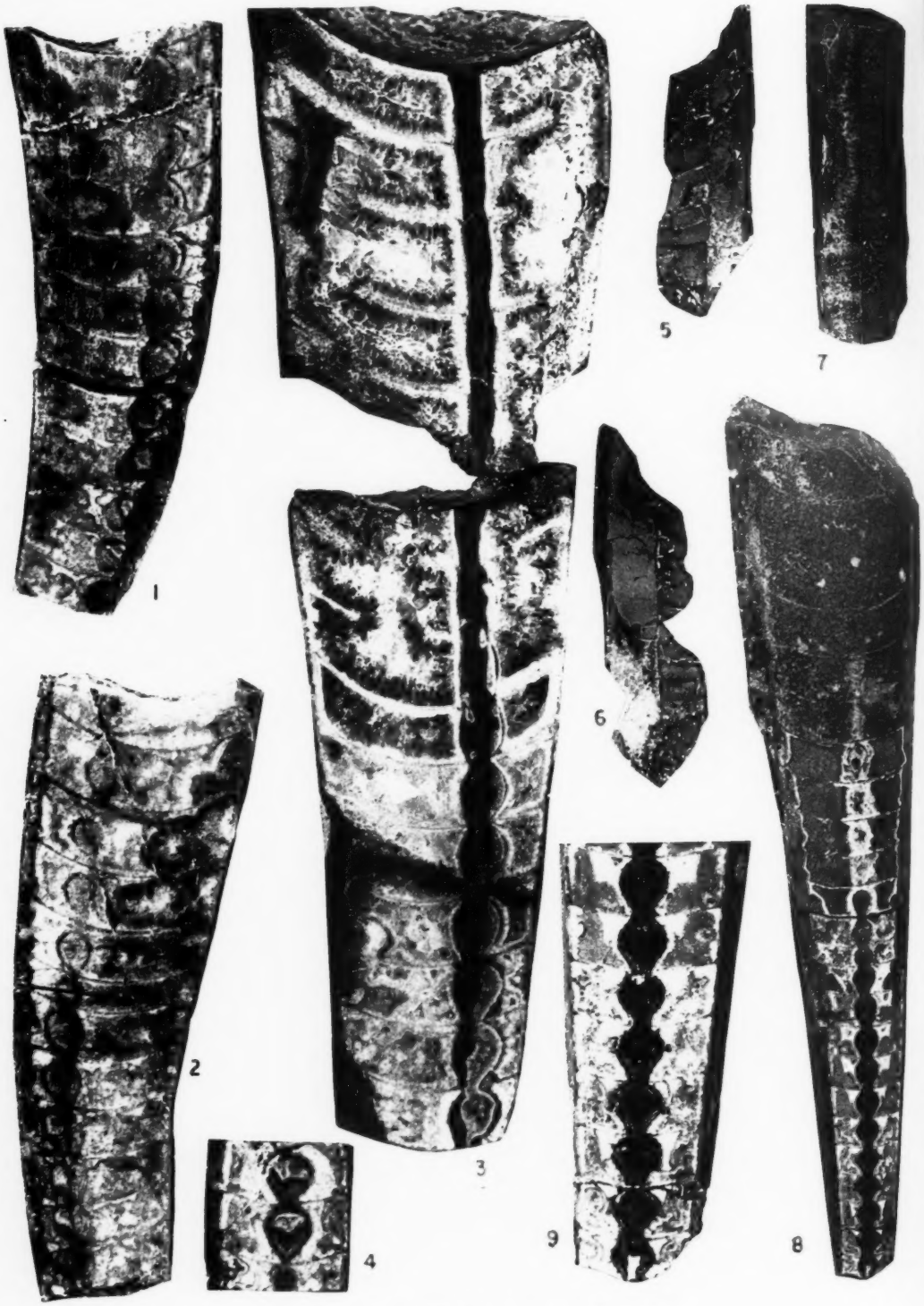
5–6—*Nybyoceras cryptum* Flower n. sp. Two halves of sectioned holotype, ×1. Note canal system at apical end of siphuncle in fig. 5, and adoral part of fig. 6. Middle Chazy, *Maclurites* beds, west of Chazy, New York. (p. 818)

7–8—*Mesnaquaceras curviseptatum* Flower, n. sp. *7*, Siphonal side of holotype, showing gentle crests and low annuli, ×1. *8*, Vertical section from apical part of fig. 7, ×1. (p. 821)

9—*Proteoceras perkinsi* (Ruedemann). Vertical section, venter on left, about ×2.5. Chazy limestone, Little Monty Bay, N. Y. (p. 822)



Flower, New Chazyan orthocones



Flower, New Chazyan orthocones

axis. The apex is obliquely broken, and the section in fig. 5, which is the ventral half, lies nearly at the middle of the siphuncle apically, but well ventrad of the center adorally, while the opposing section (Pl. 79, fig. 6) lies apically slightly dorsad of the center of the siphuncle, passing obliquely through its center in the middle segments, where the central and radial canals are clearly shown, and finally coming to a position ventrad of the center in the extreme adoral segment. Near the adapical part of this specimen there is shown evidence of the double connection of the radial canals to the central canal, typical of *Nybyoceras* and its allies. Because of the faint obliquity of the section, which passes obliquely forward so that it cuts a section across the width of the shell progressively farther from the point of greatest width of the cross section, the shell appears to be essentially parallel sided; actually a slight lateral expansion occurs. The section has a width at the earliest measurable point of 17 mm. and an estimated height of 12 mm. The siphuncle lies well ventrad of the center, and its expanded basal segments are obviously in contact with the ventral but not the dorsal wall of the shell. Seven and an incomplete basal eight segment of the siphuncle can be seen. In a horizontal section the segments appear similar to those of *Armenoceras* in the young, and more like those of *Ormoceras* in the adoral portion. The first complete segment measures 10 mm. across its widest point and is 4 mm. long; the penultimate segment is 4 mm. long and attains a maximum width of 6 mm.

A second sectioned specimen (Pl. 81, figs. 3–4) is slightly tilted from the horizontal; fig. 4 represents the ventral half but the section is inclined so that the right side is nearer the dorsum than the left; also the section passes very close to the ventral margin of the shell at its base, but slopes toward the dorsum adorally. Thus the apparent rate of expansion of the shell is increased while in the other section it was decreased. The estimated expansion of the shell is from 12 mm. and 16 mm. at the completion of the first septum to 18 and 22 mm. in a length of 30 mm. Eight segments of the siphuncle can be seen, the first incomplete, The first two seem slightly narrower than the third, because the section lies ventrad of their centers and consequently the region of their greatest width in the plane of the section; the third segment on the ventral half attains a length of 4 mm., expanding from 3 mm. to a width of 10 mm. (Pl. 81, fig. 5), the sixth segment is shown nearly at its center in the other half of the section, where it has the same length, and expands from 3 mm. to only 6 mm. The camerae are somewhat dolomitized and the cameral deposits not well shown.

A third specimen, 42 mm. in length, shows the apical septum complete in the dorsal half, which unfortunately does not expose the apical perforation, which the plane of the section has barely missed. Nine

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EXPLANATION OF PLATE 80

FIGS. *1–2*—*Proteoceras perkinsi* (Ruedemann). Opposing surfaces of vertical longitudinal section of holotype, ×2; center of siphuncle is attained at adoral end of fig. 1; and is nearly attained at apical end of fig. 2. Chazy limestone, Isle La Motte, Vermont. (p. 822)

3–4—*Proteoceras perkinsi* (Ruedemann), hypotype, ×2. *3*, Adoral portion in vertical longitudinal section showing marked ontogenetic changes. *4*, Natural transverse section from a portion apicad of that shown in fig. 3, ×1.6; showing organic deposits. Crown Point limestone, from section west of Chazy, New York. (p. 822)

5–6—*Baltoceras minor* Flower, n. sp. A syntype, vertical longitudinal sections, ×1. Lower Chazyan, South Hero Island, Vermont. (p. 810)

7—*Endoceras* sp. Vertical section, with siphuncle on left, retaining base of sipiculum at extreme adoral end. ×1. Lower Chazyan, South Hero Island. (p. 813)

8–9—*Proteoceras pulchrum* Flower, n. sp., holotype. *8*, Entire specimen, ×1, viewed from venter. *9*, Enlargement of apical part of same specimen, ×1.75, showing siphuncle and camerae in more detail. Middle Chazyan, northwest of Vergennes, Vermont. See also Pl. 81, fig. 8. (p. 825)

and a portion of a tenth segment of the siphuncle can be seen, though preservation is poor in the adoral portion. The camerae vary in length from 3.8 mm. to 5 mm., the segments of the siphuncle are, as before, broad in the basal camerae, narrow in the adoral ones, decreasing in width from 11 mm. to 5 mm. This section is almost perfectly in the plane of the central canal in the dorsal half of the specimen. Again, as can be seen, the segments of the siphuncle seem to pass from those typical of *Armenoceras* to those typical of *Ormoceras* in the short inteval of the phragmocone.

Discussion.—Although what has been considered the essential criterion of *Nybyoceras*, namely the contact of the septum with the adoral segment of the siphuncle on the venter, and with the "underlying" (adapical) ring on the dorsum, cannot be seen in our material from the nature of the sections which are nearly horizontal, there can be no doubt but that this is a typical *Nybyoceras*, for typical examples of the genus, as originally described, are breviconic shells with the siphuncle rapidly decreasing in diameter as traced orad, in relation to the extent of its expansion in the camerae. Our form is closely similar to *Nybyoceras ulrichi* Foerste & Teichert (1930, p. 278, pl. 46, fig. 1A–C) but is a diminutive species in relation to it. The large and less markedly breviconic species, including the genotype, are not closely similar (Troedsson, 1926, p. 106, see also Teichert, 1930). Kobayshi (1934, p. 451, pl. 29, figs. 1–4) has figured and described as *Kochoceras? yokusense*, a form very similar to ours in the small size of the shell, short phragmocone, and the siphuncle which is broad at the base and becomes rapidly narrower as it approaches the living chamber. This form, from its rapid ontogenetic change, was an actinoceroid similar to ours with a very short phragmocone. Both that and the present species seem to be more consistent with *Nybyoceras* than with *Kochoceras*, and indeed it might be possible to set both of these forms apart in a new genus distinct from either; however, in doing so I would not be certain in which category *N. ulrichi* would fall. It is therefore not possible to make a clear separation at the present time, and a new generic name would probably serve only to confuse the nomenclature, as has already been done amply for actinoceroids (Shimizu & Obata, 1936).

Types.—Holotype and three paratypes, collection of the writer.

Occurrence.—This species is rare in the Crown Point limestone. The holotype is from the *Maclurites* ledges west of Chazy, New York; two paratypes are from ledges of Chazyan four miles northwest of Vergennes, Vermont, and three-fourths of a mile east of Porter Bay, in beds regarded as of essentially the same age, associated with *Maclurites, Gonioceras chaziense, Stereospyroceras*, and *Proteoceras pulchrum. Meniscoceras coronense* was found at the same locality, its first occurrence outside of the section at Crown Point, New York.

Family MICHELINOCERATIDAE

Genus MESNAQUACERAS Flower, n. gen.

Genotype: *Mesnaquaceras curviseptatum* Flower, n. sp.

Shell orthoconic, slender, surface developing low distant annuli; no finer surface markings known. Septa widely spaced, deeply curved, sutures essentially straight and transverse. Siphuncle markedly eccentric, close to ventral (?) side, composed of orthochoanitic septal necks and connecting rings which form segments slightly expanding within the camerae. Annulosiphonate deposits are developed in the siphuncle which grow orad along the siphuncle wall from their point of origin at the septal foramina, but do not fuse to form a continuous lining as in *Virgoceras* and the Pseudorthoceratidae. Thin episeptal and hyposeptal deposits are developed in the camerae. Shell compressed in cross section.

Discussion.—The internal structure of this form suggests a small group of species of younger Ordovician smooth shelled types exemplified by *Orthoceras ludlowense* of the Cynthiana limestone of Kentucky. It is combined here with an annulated shell which is further remarkable among Ordovician orthoceracones in having a compressed cross section. Since Hyatt (1884, 1900) separated annulated shells with longitudinal markings as the genus *Spyroceras*, and those with transverse markings as *Cycloceras* there has been a widespread notion that all annulated shells should fit

into one cateogry or the other; this form is clearly externally smooth. Aside from the obvious fact that this genus belongs to the Michelinoceratidae, its affinities are not particularly evident. It is erected for the reception of a single Chazyan species described below. I know of no close relatives of this form.

MESNAQUACERAS CURVISEPTATUM
Flower, n. sp.
Pl. 79, figs. 7–8

Shell straight, slender, slightly compressed in cross section, the shell about 4 mm. greater in height than in width throughout. Dorsum and venter equally rounded in cross section; shell expanding in height from 18 mm. to 25 mm. in the basal 45 mm. of the type, and to 30 mm. in the adoral 45 mm. Sutures straight and transverse, camerae deep, about two occupying a length equal to the adoral height of the shell. Septa very deeply curved, 6 mm. in depth at a shell height of 21 mm. Siphuncle strongly eccentric, its center 4 mm. from the venter and 15 mm. from the dorsum at the base of the type, 20 mm. from the dorsum and 5 mm. from the venter at the adoral end of the sectioned portion, and evidently retaining a ventral position throughout life. A segment 10 mm. long expands from 2 mm. at the septal foramen to 3 mm. within the camerae. Large annuli occupy the siphuncle, thick at the septal foramen, where they leave only a small central perforation, and extending orad along the inner surface of the connecting ring, in rare cases extending far enough to fuse with the deposits of the next adoral segments, but not merging with them in outline. Deposits are in general more advanced in growth on the dorsal than on the ventral side of the siphuncle. The free parts of the septa are supplemented by thin episeptal and slightly thicker hyposeptal deposits, poorly developed on the small region between the siphuncle and the ventral wall, but much better seen on the dorsal side of the siphuncle.

In the above description the siphonal side of the shell has been assumed to be ventral; there is no real morphological evidence as to the correct orientation of the shell; it is possible that the siphuncle is dorsal. However, with no real evidence either way, the usual orientation with a ventral siphuncle has been assumed.

The shell surface is marked by low faint annuli, five in a length of 20 mm. There are no finer markings. The surface is preserved only on the siphonal side, and there is a faint suggestion that the annuli slope slightly apicad on the lateral regions of the conch and may, indeed, be slightly oblique. If so, the antisiphonal side of the shell may be the venter, but the evidence is extremely inconclusive. Neither conchial nor septal furrows are evident.

Discussion.—The generic characters will serve to distinguish this species. There are no slender deeply camerate and faintly annulated shells in the Chazyan, or the entire Middle Ordovician for that matter, which can be readily confused with this form.

Holotype.—Collection of the writer.

Occurrence.—From the lowermost shaly limestones of the Chazyan, one and one fourth miles southwest of South Hero, along ledges on west side of road leading south from South Hero village to the shore east of Phelps Point, South Hero, Vermont.

Family STEREOPLASMOCERATIDAE
Genus PROTEOCERAS Flower, n. gen.

Genotype: *Oonoceras perkinsi* Ruedemann

Shell slender, the apical portion often slightly curved, anterior portion straight. Orientation uncertain; curvature probably endogastric. Siphuncle relatively close to convex (dorsal?) side of shell in young, more nearly central in later stages. Shell smooth, sutures straight and transverse. Segments of siphuncle expanded in early segments, expanding rather abruptly from the septal necks, and then contracting in apical portion more gradually. Necks short, recurved, no area of adnation. Annular deposits in the apical part of the siphuncle tend to be thick on either side of the septal neck, but are usually wanting over the most constricted part of the septal foramen. A secondary deposit of calcite may nearly fill apical camerae; adorally it tends to fill a large part of the supposed dorsal side of the siphuncle. Camerae with mural deposits, often elaborate in vertical section, more

strongly developed on the concave than on the convex side of the shell. Adoral parts of the phragmocone may lack deposits of both camerae and siphuncle. As the siphuncle is traced forward in the phragmocone the expansion of its segments is reduced and finally lost, so that late portions of the phragmocone alone would be assigned to *Michelinoceras* without knowledge of the early stages.

Discussion.—This genus is remarkable for the rapid changes in form and structure. The shells are presumably slightly curved endogastrically in the apex, though in *P. pulchrum* and *P.* cf. *P. moniliforme* stages sufficiently early to show such curvature are unknown. The shallow septa of the young give way to more deeply curved ones, and the originally transverse sutures tend to slope forward on the ventral side. The siphuncle moves from a position close to the convex side of the shell to a position closer to the center of the shell. Its segments, broadly expanded in the young, become orthoconic and tubular in late stages.

The endogastric interpretation of this genus is the reverse of the orientation that would normally be attributed to such species as are included in it. It is indicated by three facts: (1) the antisiphonal side bears a longitudinal ridge on the interior which appears to be a conchial furrow, (2) cameral deposits are concentrated against the concave and not the convex side of the shell, (3) siphonal deposits are concentrated on the side of the segments here interpreted as ventral. Of these criteria, none are necessarily conclusive except the conchial furrow.

A vexing fact shown conclusively by the present material is that late portions of the phragmocones of this genus could be mistaken for *Michelinoceras*. Yet there is true *Michelinoceras* in the Chazyan, represented by specimens retaining the usual slender tubular siphuncle down to the earliest known growth stage, a shell diameter of about 4 mm.

The interiors of the specimens described below present some vexing problems. Clear organic deposits are present in the adapical segments of the siphuncle. They thin in adoral segments and disappear. There is, however, white calcite in more adoral segments, which shows no organic structure, and is presumably the complement of an incomplete internal mold of sediments. It is a curious fact, however, that the sediments in all specimens penetrate the siphuncle farthest on the supposed ventral side of the shell. While the concentration of cameral deposits would tend to cause the shell to rest with that side beneath, the curvature of the shells would tend to cause them to lie on a lateral surface. While the postion of the specimens in the beds was not noted in general, except for the holotype of *P. pulchrum*, which is essentially straight and did rest with the antisiphonal ventral side beneath, it seems unlikely that all specimens were uniform in position. It is therefore considered possible that the white calcite may represent some organic structure, possibly poorly calcified, though its interpretation admittedly requires much more material than is now available. Representatives of this genus are rare in the Chazyan. My collecting has resulted in only five representatives of the genus over a period of years.

The genotype is redescribed below, with the addition of the new species *P. pulchrum*, and one other specimen is assigned tentatively to *Orthoceras moniliforme* Hall. I have not had, however, typical representatives of that little known species available for the present study.

In addition to these forms from the Chazyan of the Champlain Valley, the only species which seems referrable to the genus *Proteoceras* is *Orthoceras diffidens* Billings of the Mingan formation which Foerste (in Twenhofel, 1938) referred to *Dieroceras*. The species is certainly not a true *Dieroceras;* in general form it agrees with *Proteoceras*, but the extant descriptions and illustrations do not supply information concerning the cameral or siphonal deposits in sufficient detail. There is also a possibility that some Mohawkian species formerly assigned to *Sactoceras* (Foerste, 1932–33) may belong either here or in a closely related genus, but again detailed information of the structure required to test this possibility, is not included in the descriptions of these forms.

PROTEOCERAS PERKINSI (Ruedemann)
Pl. 79, fig. 9; Pl. 80, figs. 1–4; Pl. 81, fig. 5

Oonoceras perkinsi RUEDEMANN, 1906, New York State Mus., Bull. 90, p. 499, pl. 34, fig. 4–5, text fig. 53–54.

The holotype of this species is a portion of a phragmocone 45 mm. long, expanding from 10 to 16 mm. in height. The cross section appears to have been slightly wider than high, but the type, when it came into my hands, had been sectioned vertically, and the exact amount of material lost in sectioning is uncertain. The type contains eleven camerae and most of a twelfth one. The vertical section is slightly askew, so that the center of the siphuncle is attained at the adoral end of one side (Pl. 80, fig. 1), and the center is nearly attained in the adapical part of the opposite side (Pl. 80, fig. 2). Sutures appear to be straight and transverse. Septa gently curved, the curvature equal to about three-fourths the depth of the camerae. Nearly five camerae occur in a length equal to the adoral shell height apically; adorally three and a half camerae occur in a similar length. Apically the center of the siphuncle is twice as far from the concave (ventral?) side as from the dorsum; adorally the siphuncle is only slightly more centrally located.

Septal necks short, recurved, equal to one-fifth to one-sixth the depth of the camera. Apically, a segment 3 mm. long expands to a maximum width very nearly equal to the length of the segment; the septal foramen is equal to one-half the diameter of the siphuncle segment at its largest point. Adorally the segments are more slender and the curvature of the septal neck is somewhat reduced. The maximum diameter of the siphuncle segment remains nearly twice that of the septal foramen. Throughout, the side of the siphuncle close to the convex (dorsal?) shell wall is markedly more expanded than is the opposite side.

The anterior three segments of the siphuncle show only a filling of inorganic calcite and the connecting ring is apparently absent on the ventral side. The fourth segment shows some black material unevenly distributed along the connecting ring; the fifth shows a definite band of dark material against the connecting ring on the ventral side. The next segment shows this material thickened, and is plainly an organic deposit. The section (Pl. 80, fig. 1) is slightly off center, and shows some similar material passing from the apical end part way forward on the inside of the connecting ring on the ventral side of the siphuncle. The apical segments, best seen in the opposite side, show an evident rapid increase in the thickness of the deposits, so that there is in each segment a central tube which widens at the anterior end as it approaches each septal foramen. Within the material of this deposit obscure lamellae of growth can be seen. The apical three segments show on the dorsal side only a smaller darker deposit, which in vertical section seems to be an annulosiphonate deposit. It is atypical, however, in that it is apparently divided into an anterior and a posterior region, and is clearly not continuous over the septal foramen. As will be seen from other sections, there is reason to believe that these two parts of the deposit are actually two discrete entities, the one an outgrowth of the anterior end of one connecting ring, the other an outgrowth from the apical part of the next succeeding ring.

Between the siphuncle and the convex wall of the shell is a band of dark calcite which represents rather poorly preserved thin cameral deposits. Much thicker cameral deposits lie against the concave wall of the shell, but they also are poorly preserved, and while their form is indicated it is not possible to say from this specimen which parts of the calcite represent the true organic deposits, and which are parts of the inorganic calcite formed within the space remaining in the camerae, for the inorganic calcite may show layering which follows the outlines of the organic deposits fairly closely. It is evident from the adoral camerae of Pl. 80, fig. 2, that the organic deposits thicken rapidly when traced apically from one camera to the next. In apical camerae, where their growth is probably so advanced that the space between the siphuncle and the concave ventral wall is nearly if not completely filled, their outline and structure are obscure.

A second specimen is one from the Valcour limestone of Little Monty Bay, showing much clearer preservation. The specimen consists of four rather poorly fitting pieces, owing to the friable nature of the calcite filling the camerae, 104 mm. long in all (Pl. 80, figs. 3–4). The apical portion 28 mm. long, is weathered at the base, the weathered surface extending from the concave ventral wall adorally obliquely to the dorsum, and showing a transverse obliquely

longitudinal section of the siphuncle. At its adoral end the cross section is 11 mm. high and 12 mm. wide. The natural section of the siphuncle (Pl. 80, fig. 4) shows well developed deposits which are concentrated in the apical half of the siphuncle. The section illustrated is off center, and the deposits of the two sides are therefore seen to ioin in the middle of the section.

The remainder of the shell, 81 mm. long, increases vertically from 11 to 27 mm., and contains fifteen camerae. The shell is slightly curved in the apical portion, essentially straight adorally. In the basal four camerae the siphuncle is very similar to that of the holotype in the outline of the segments. Septal necks are slightly recurved, short, the siphuncle expanding to a maximum height of twice its diameter at the septal foramen; the dorsal outline is somewhat more expanded than the ventral one. Cameral deposits are suggested by the calcite in the camerae, but are not clearly preserved. The basal segment of the siphuncle shows a lamellar organic deposit of some thickness against the ventral wall. It occupies the greater part of the length of the connecting ring, but thins rapidly as it approaches its adapical end. A thin obscure black organic deposit can be distinguished from the matrix in the succeeding two segments, but cannot be traced farther orad.

The next six camerae of the next piece show a progressive lengthening of the segments, and a simplification of their outlines. The last portion of the specimen contains five camerae in which the outline of the siphuncle has become so simplified that the septal necks are essentially straight. At the base of this portion, the connecting ring outlines a segment which is straight on the ventral side, very slightly expanded on the dorsum. The adoral two camerae, however, show segments which are essentially tubular in both dorsal and ventral profiles, and the connecting ring is so slightly bent that its tip points inward, instead of being parallel to the axis of the siphuncle. No deposits are present in the adoral camerae. As the siphuncle is traced orad, the white calcite which occupies the dorsal portion near the apex thins and finally disappears. The middle of the specimen shows a few white spots of calcite in the siphuncle which have no organic significance; the adoral part of the siphuncle contains only the grey lime mud of the matrix.

The specimen also illustrates a marked change in the curvature of the septa in ontogeny. The early septa are only slightly curved in vertical section, and the dorsal and ventral juncture of the free part of the septum with the shell wall indicates a suture which is essentially transverse. In the adoral part of the shell the septa are much more strongly curved, and the sutures have evidently come to slope forward appreciably on the ventral (antisiphonal) side of the shell.

A third specimen from the upper Chazyan near Little Monty Bay (Pl. 79, fig. 9) is a portion of a phragmocone 48 mm. long sectioned nearly but not quite vertically. Its height increases from 15 to 18 mm. in the 22 mm. in which the height can be measured; the estimated expansion throughout its length is from 13 to 20 mm. This shell shows a region anterior to that shown by the holotype, where the segments of the siphuncle are becoming markedly slender. The small diameter of the adoral segments, however, deceptive; the section at this end does not attain the center of the siphuncle and does not show its full diameter. Cameral fillings in this specimen are largely inorganic calcite, but near the base thin organic deposits are developed in the lower left of the figured section. On the left of the siphuncle is a dark band, thick adorally, thin adapically, which is an incomplete filling of the black lime mud of the matrix. The bands of white calcite lining the siphuncle are largely inorganic, but a thin organic deposit is present in the apical four segments. The section is inclined nearly 30 degrees from the vertical; consequently the siphuncle appears to be more centrally located than in the other more vertical sections.

Types.—The holotype is in the collection of the University of Vermont; the two hypotypes are in the collection of the writer.

Occurrence.—This species is known only from the middle and upper Chazyan. The holotype is from Isle La Motte. Whether it is from the Crown Point or Valcour limestones is doubtful. Of supplementary material, two specimens, one of which is not em-

ployed in the above descriptions, are from the reefy beds of the Valcour limestone southeast of Chazy and west of Little Monty Bay. One other specimen is from the upper part of the *Maclurites* ledges of the type section of the Chazyan, west of Chazy, New York. It is from a thin band of relatively pure limestone, packed with *Maclurites* and yielding occasional cephalopods, exposed in a small quarry south of the Chazy-West Chazy road, lying stratigraphically above the main ledges so beautifully exposed on the north side of the road, and directly beneath the *Stromatocerium* bearing beds (B4 of Brainerd & Seely).

PROTEOCERAS PULCHRUM Flower, n. sp.
Pl. 80, figs. 8–9, Pl. 81, fig. 8

In this species the known portion of the shell is straight, relatively rapidly expanding, the sutures slope forward slightly on the venter, and the camerae are relatively deep. The holotype is a portion of a phragmocone 128 mm. long, incomplete at both ends. As represented in the illustration (Pl. 80, fig. 8) the shell is seen from the dorsal (siphonal) side. The adoral part represents a natural weathered section; apically a section was ground exposing the siphuncle, in a longitudinal transverse section. The shell surface is featureless, showing only the faintest suggestion of growth lines. The cross section was originally slightly wider than high. Lateral expansion is moderate, the shell increasing from 12 to 19 mm. in the basal 55 mm., and to 26 in the adoral 60 mm. The antisiphonal surface has been examined by exfoliation, grinding and gentle etching, but has failed to reveal traces of the conchial or septal furrows.

The free parts of the septa are relatively gentle in curvature throughout the known portion, as in the early stages of *P. perkinsi*. The camerae are spaced three and a half in a length equal to an adoral shell width of 14 mm., increasing to four and a half at 18 mm., and returning to three and a half at 24 mm.

The basal eleven segments of the siphuncle are well exposed in a horizontal vertical section. Septal necks short, recurved, segments of siphuncle attaining their greatest diameter near the adoral end, and tapering more gently apically, joining the preceding septum with no perceptible area of adnation. Deposits within the siphuncle are annular in appearance, but as in *P. perkinsi* are interrupted at the septal foramen, and actually consist of two distinct parts, the one a deposit which is apparently derived from the anterior end of one connecting ring, the other a deposit derived from the apical end of the connecting ring of the next adoral segment. The deposit formed in the apical part of the segment is constant and regularly developed. The one formed at the adoral end is irregular, and cannot be seen in all segments. Both deposits plainly grow by the secretion of additional layers of calcareous material to the entire surface of the deposit, rather than to its adoral end.

The natural section of the anterior end of the specimen passes below the level of the siphuncle, which is faintly indicated basally and is lost adorally. What can be seen suggests that at a shell width of 22 mm. the outline of the segments is becoming more slender, as already shown in better material of *P. perkinsi*.

Cameral deposits are well developed, and can be seen clearly in the basal sectioned part. Their margins are also well displayed by light lines in the anterior natural section; there the greater part of the deposit is replaced with relatively dark slightly dolomitic material.

Discussion.—This species differs materially from *P. perkinsi* in the straighter form of the early portion, the somewhat different spacing of the camerae. It agrees with *P. perkinsi* in the essential internal features. An effort was made to examine the antisiphonal side of the shell for possible conchial and septal furrows. Neither structure could be demonstrated. It is reasonably certain that there is no septal furrow; such a structure would almost certainly have been found by removal of the shell wall, grinding and etching. It is quite probable however, that the conchial furrow would not be visible under the present conditions of preservation, and by these methods of study. It is commonly displayed only in well preserved shells which have separated between the shell wall and the mural part of the septum.

Types and occurrence.—The holotype, in the collection of the writer, is from the

middle Chazyan ledges exposed in fields one and one half miles northwest of Vergennes, Vermont.

PROTEOCERAS cf. P. MONILIFORME (Hall)
Pl. 79, fig. 4; Pl. 81, fig. 2

I tentatively assign to this species a portion of a phragmocone consisting of two parts. The apical portion is sectioned inclined 30 degrees from the vertical; the adoral part is a vertical longitudinal section. Together the two pieces include a portion of phragmocone 63 mm. in length, preserving 14 segments of the siphuncle and most of the adjacent camerae. The shell is straight, slender, expanding from 15 to slightly less than 17 mm. in 20 mm., while in typical *P. pulchrum* the shell would increase to 19 mm. in a similar length. Between three and three and one-half camerae occupy a length equal to the adoral shell height, with due allowance made for the fact that a small portion of the shell is missing on the siphonal side over most of the length of the specimen.

The segments of the siphuncle are typical in form, and their expansion is fairly uniform throughout the length of the specimen. Near the anterior end are two camerae longer than the rest. Light calcite crossing them suggests that this lengthening may have been inorganic, and that it is the result of the deposition of inorganic calcite in these camerae; the adoral two camerae are more typical in depth, and they show siphuncle segments of more typical outline. The apical portion (Pl. 81 fig. 2) has seemingly a smaller septal foramen, an appearance due to the position of the section which was accidentally ground slightly beyond the center of the siphuncle.

The apical segments of the siphuncle show a black lining which passes through the septal foramen, a feature not observed in other specimens of the genus. Its presence here may indicate an unusual late stage of the growth of the deposits; it may be that some carbonaceous material, possibly derived from the tissue of the connecting ring, is here present, and poorly differentiated from the original calcareous deposits. The lowermost complete segment at the base of the specimen shows a grey organic deposit against the ventral wall; a black deposit crosses the septal foramen in the plane of the section, and extends forward over the dorsal wall of the siphuncle for a short distance. In the next segment, where the section is more central, the adapical termination of the deposit is clearly seen, and the structure appears to be original and organic against both the dorsal and ventral walls, though black material lying against the surface of the deposit of the ventral wall is apparently inorganic sediment. As the segments of the siphuncle are traced orad, the amount of dark material against the ventral wall increases, and is continuous from segment to segment in the anterior portion. It is plainly sediment.

The camerae are filled with calcite. Against the dorsal wall the pattern of the cameral deposits is seen in section very clearly. Certainly the area between the ventralmost dark line and the shell wall represents organic deposits. In most camerae there is between this and the siphuncle a broad band of calcereous material the inner surface of which conforms fairly well to the vertical pattern of the deposit just mentioned. It is not certain whether this represents the outer portion of an inorganic deposit, which often shows layering conforming to the shape of the cavity in which it develops, or whether the section may represent here some such lobe of the organic deposits as has been found to exist in *Pseudorthoceras* (see Flower, 1939, p. 37, fig 9B, also pl. 1, fig. 6).

Discussion.—The specific relationships of this species are doubtful. The proportions are clearly different from those in commensurate parts of *Proteoceras perkinsi*, from which our form differs in the essentially straight shell, gentle expansion, and slightly different spacing of the camerae. *P. pulchrum* is straight as is this form, but the shell is much more rapidly expanding, the sutures slope forward on the venter, which they clearly do not do in this species, and the camerae are somewhat different in proportions. Typical *Proteoceras moniliforme* is not well enough known for close comparison, but the present specimen is close to the type specimen in the straight form, the rather close spacing of the septa, and agrees with one of the two specimens figured by Ruedemann (1906, pl. 34, fig. 7) in having

apparently straight and transverse sutures. The second specimen which Ruedemann attributed to the species is a *Proteoceras*, but one with much deeper camerae. It shows no deposits in the camerae or siphuncle. It probably represents an otherwise undescribed species.

The figured specimen in the collection of the writer, is from the upper Chazyan, Valcour limestone, from the reefs near Little Monty Bay, New York.

Genus STEREOSPYROCERAS Flower, n. gen.
Genotype: *Stereospyroceras champlainense* Flower, n. sp.

Shells straight, prominently annulated in young; with fine longitiduinal markings, sometimes fainter transverse markings. Shells have a tendency toward slight exogastric curvature, and toward a reduction of annuli in the late stages of some of the larger species. Siphuncle with small segments, biconvex in outline in young, tending to become planoconvex in vertical section and finally approaching the orthoconic in extremely late stages. Camerae with organic deposits, mainly episeptal, and similar to those of other Stereoplasmoceratidae in the massive nature of the deposit between the suture and the siphuncle. Siphuncle with annular deposits, rather irregular, but relatively thick, produced both orad and apicad of the point of inception; secondary organic lining not typically present.

Discussion.—This genus differs from *Gorbyoceras* in several respects, the prominence of the annular deposits, the massiveness of the cameral deposits, and the development of cameral deposits far in advance of the siphonal deposits. Both cameral and siphonal deposits are typically well advanced, and are not confined to relatively apical portions of mature shells as in typical *Gorbyoceras*. The two genera are doubtless related, but are distinct enough structurally to merit recognition as separate entities. At the present time there appears to be a stratigraphic break also, for *Stereospyroceras* is known only from the Chazyan, while *Gorbyoceras* is definitely recognized only in the Cincinnatian. Species from the Trenton and Black River to connect these two groups are not yet adequately known, though they may well exist in some species, inadequately known internally as yet, currently assigned to "*Spyroceras*" in the old sense as a form genus for annulated orthocones with dominantly longitudinal ornament.

The Chazyan shells which constitute *Stereospyroceras* were formerly included in *Orthoceras clintoni* Hall. Actually, there is much variation in proportion, and quite evidently there are at least seven species in the Chazyan. A problem surrounds just which of these species is actually *Orthoceras clintoni*, and therefore as a genotype I have selected one of the undescribed species which is certainly distinct from Hall's type of *S. clintoni*, in order to remove any possible perplexities due to synonymy of species and confusion which might arise concerning the identity of the genotype.

STEREOSPYROCERAS CHAMPLAINENSE Flower, n. sp.
Pl. 81, figs. 1, 9

The holotype is a portion of a shell 155 mm. in length, sectioned parallel to a natural weathered surface which was oblique to the shell axis. The vertical plane passes through the siphuncle obliquely down to the left side of the specimen as oriented in the figure showing the polished section. The shell expands in height from 26 to 41 mm. in the basal 100 mm; and to 45 mm. in the remaining 55 mm. The cross section was evidently slightly wider than high, but the exact ratio of height and width can only be surmised, except to say that the difference between them was relatively slight. The siphuncle is slightly closer to the venter than the dorsum in the early portion, becoming more excentric in later stages. Apically the siphuncle which is 4 mm. in diameter at the foramen, is 13 mm. from the dorsum and probably 11 mm. from the venter; adorally it is 16 mm. from the dorsum 4 mm. in diameter, and an estimated 11 mm. from the venter.

Siphuncle segments slightly expanded, but slender, and showing no significant difference in dorsal and ventral profile, as is true of some other species of the genus. A segment 12 mm. long increases from 4 to 6 mm. in diameter within the camerae.

Septal necks short, recurved beyond the vertical, but without definite brims. Annular deposits are present within the siphuncle, tending to grow dominantly forward rather than apicad, rather irregular, and apparently thicker and more advanced on the dorsal than on the ventral side.

Cameral deposits are remarkable in that they are present, though thin, in the last camera; usually a considerable adoral part of the phragmocone lacks these structures. On the venter episeptal deposits are normal, scarcely reaching the siphuncle, thickest against the corner of the camera marked by the suture. Thin hyposeptal deposits are present there also, but they are inconspicuous. On the dorsal side the hyposeptal deposits are greatly thickened midway between the shell wall and the siphuncle. Episeptal deposits are present, but extremely thin. In 112 mm. there are eleven camerae increasing gradually orad in depth from 9 to 13 mm. Sutures are straight and transverse. Only the base of the living chamber is preserved. The apical part of the shell shows low obscure rounded annuli, very slightly more widely spaced than the camerae. Adorally they become so faint that they cannot be measured accurately. The shell surface, of which only a small fragment is preserved, is kionoceroid in aspect, bearing alternate lirae and striae, longitudinal, with some alternation in strength of the markings, and finer transverse markings.

The shell is very faintly curved, the dorsum slightly concave.

Discussion.—This species is distinctive in the proportions, the adoral suppression of annuli, the siphuncle, which remains at essentially a uniform distance from the venter in the known portion regardless of the increase in the diameter of the shell as a whole. It is unique among the shells that I have had an opportunity to study closely in the retention of cameral deposits in the last camera, though this condition is approached but not attained in some completely unrelated species of *Michelinoceras* and *Geisonoceras* in the Middle Silurian of Bohemia.

In the groups of species formerly embraced in *Orthoceras clintoni*, this species is set apart by the above characteristics. Others show great variation, from extremely slender tapering shells with uniformly spaced annuli and siphuncles which become slender adorally, to a form with strongly elevated annuli in a late growth stage, relatively rapid expansion, slight curvature, and a siphuncle which becomes tubular, to forms which show both a loss of annuli and of the expansion of the siphuncle in the late growth stages.

Holotype.—Collection of the writer.

Occurrence.—From the middle Chazyan, near Vergennes, Vermont.

VALCOUROCERAS TENUISEPTUM (Hall)

Orthoceras tenuiseptum HALL, 1847, Paleontology of New York, vol. 1, p. 35, pl. 7, fig. 6; —, RAYMOND, 1902, Bull. Am. Paleontology, vol. 1, no. 14, p. 19 (?)

Cameroceras tenuiseptum RUEDEMANN, 1906, New York State Museum, Bull. 90, p. 408–10 (pars) (not pl. 3, fig. 1–2, pl. 4, fig. 1, pl. 5, fig. 5–6, pl. 6, fig. 2.

Hall's type of *Orthoceras tenuiseptum* is a fragment of a shell showing a nearly vertical longitudinal weathered surface. The shell is nearly straight, faintly exogastric, the septa are extremely thin and closely spaced. There is no trace of a siphuncle. Apparently the specimen was weathered slightly beyond its center. Ruedemann (1906) believed this form to be an endoceroid, and identified with it a number of endoceroids with very closely spaced septa. He assigned the species to *Cameroceras*. Restudy of the type, Ruedemann's material, and much supplementary material leads to the following conclusions: (1) No true endoceroid of the Chazyan has proportions agreeing with those of Hall's type; (2) were Hall's type an endoceroid, there is enough to the shell present that one would expect some trace of the relatively large siphuncle which characterizes the endoceroids; (3) the spacing and curvature of the septa are inconsistent with any known *Endoceras*, but are to be duplicated in the known species of *Valcouroceras*, some of which are scarcely curved in mature portions. The present described species (Flower, 1943) obviously do not represent all of those present in the Chazyan.

The endoceroids which Ruedemann attributed to this species may not be conspecific. The types show the siphuncle wall

imperfectly, and details of the endosiphuncles are obscure. Restudy with much supplementary material is required before accurate generic or specific diagnosis can be made. Ruedemann's material came largely from three localities, the New York shore at Valcour, the east side of Valcour Island, and beds southeast of Chazy and west of Little Monty Bay.

The Valcour shore contains a variety of endoceroids, which are somewhat crushed, and usually fail to retain good endosiphuncles. Ruedemann recognized here two species, *Cameroceras tenuiseptum*, and a large form with deep camerae, *Endoceras magister*. Among the closely septate shells there occur here more than one species, and probably more than one genus. One phragmocone I tentatively assign to *Lamottoceras*, other closely septate shells are more generalized in their endosiphuncles and are probably referable to *Endoceras* in its present broad sense. A large apical portion of a siphuncle of the *Nanno* persuasion is there, which could conceivably be the initial portion of *E. magister*, though an exact identification is not warranted by the present available material.

The assemblage at Little Monty Bay contains abundant endoceroids, and probably there are more than the three species originally recognized, *C. tenuiseptum*, *C. curvatum* and "*Vaginoceras*" *oppletum*. The specimens from the dove colored limestones of Valcour Island are from a similar association, and presumably belong also to the Valcour limestone. They are not nearly as rich in cephalopods as the Little Monty Bay association, but represent essentially the same faunal assemblage. Hall's type came from the type section of the Chazyan west of Chazy, New York. Extensive collecting has yielded similar fragments clearly assignable to *Valcouroceras*, but no true endoceroids of similar proportions. The holotype is in the New York State Museum.

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EXPLANATION OF PLATE 81

FIGS. *1, 9*—*Stereospyroceras champlainense* Flower, n. sp. *1*, Apical portion of siphuncle, ×2. *9*, Entire specimen ×1, showing sectioned surface, oblique to vertical plane. (p. 827)

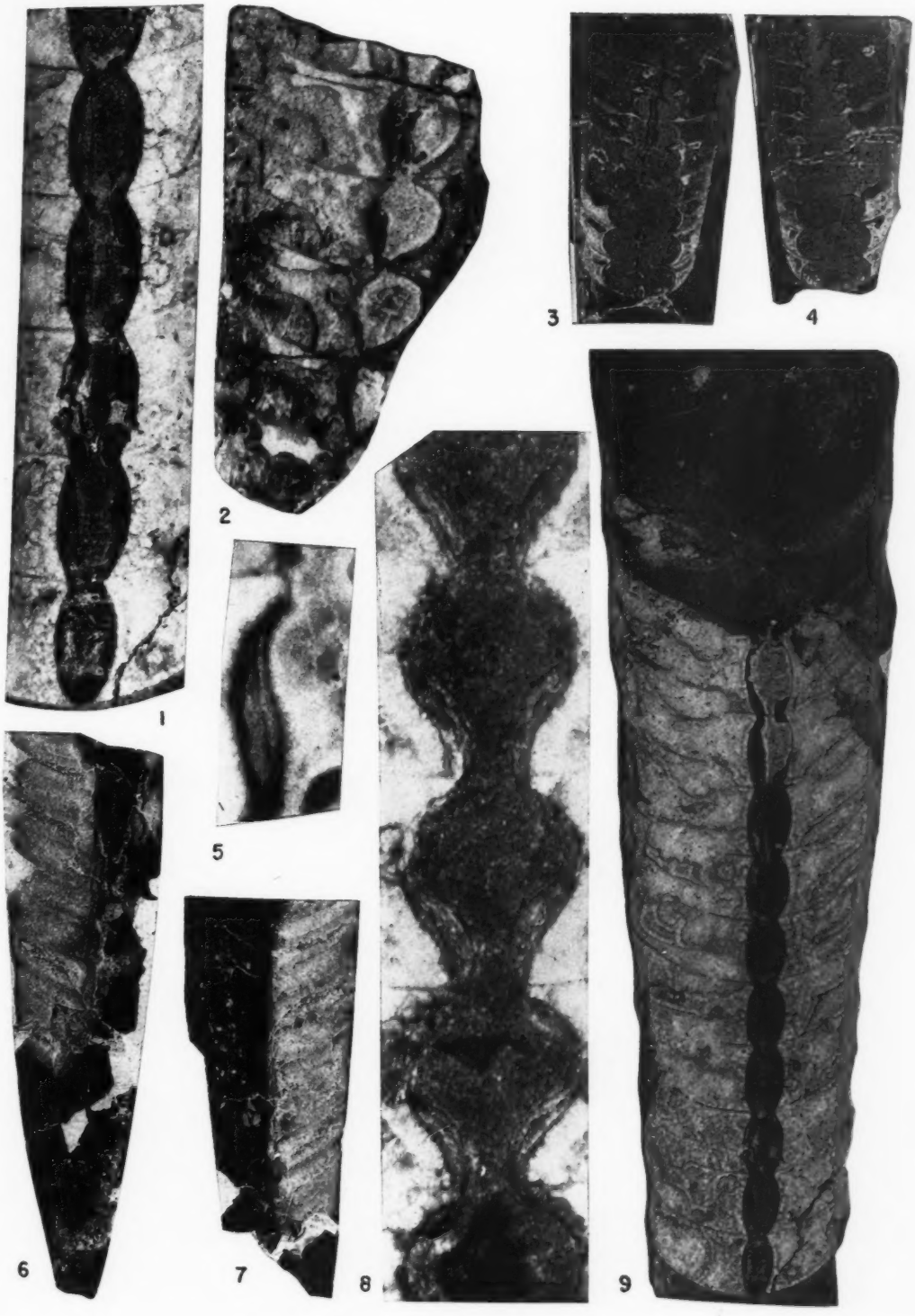
2—*Proteoceras* cf. *P. moniliforme* (Hall). Nearly vertical section of apical portion of same specimen as Pl. 79, fig. 4, showing well developed cameral and siphonal deposits. ×3.4. (p. 826)

3–4—*Nybyoceras cryptum* Flower, n. sp. Paratype, longitudinal sections slightly oblique to horizontal plane. ×1. Middle Chazyan, near Vergennes, Vermont. (p. 818)

5—*Proteoceras perkinsi* (Ruedemann) Enlargement (×7.5) of portion of apical segment of Pl. 80, fig. 3, showing septal neck and lamellae or siphonal deposit. (p. 822)

6–7—*Nanno*, n. sp. Vertical section of fragmentary specimen, ×1. Fig. 6 shows the apical portion clearly, but passes obliquely to one side of the siphuncle. Fig. 7 opposes the adoral part of fig. 6, and shows a section essentially through the center of the siphuncle. (p. 812)

8—*Proteoceras pulchrum* Flower, n. sp. Enlargement of segments 3–7 of the holotype, ×9, showing details of structure. See also Pl. 80, figs. 8–9. (p. 819)



Flower, New Chazyan orthocones

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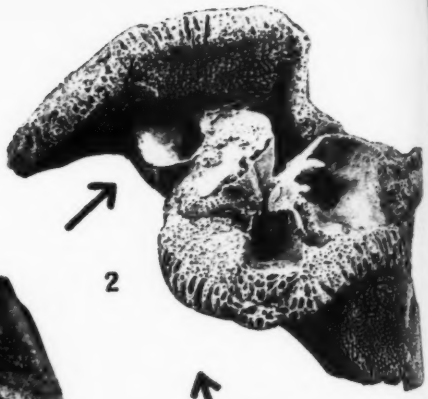
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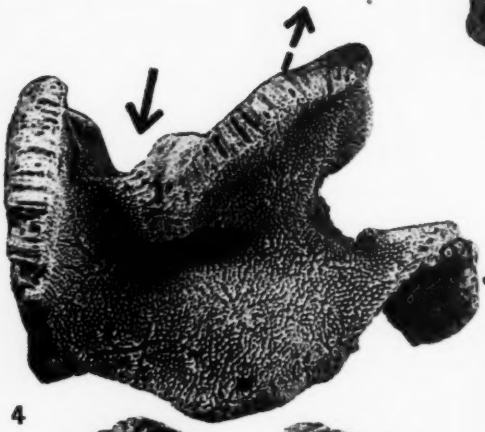
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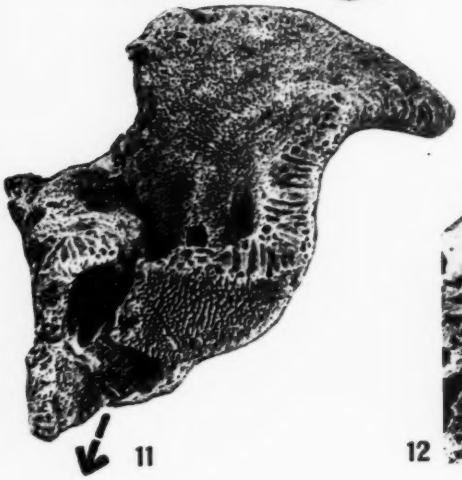
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JOURNAL OF PALEONTOLOGY, VOL. 29, NO. 5, PP. 831–836, PL. 82, SEPTEMBER 1955

CONULARIA IN A SPONGE FROM THE WEST TEXAS PERMIAN

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ABSTRACT—*Conularia leonardensis* Finks, n. sp., from the West Texas Permian is described, and some biological observations are made on an association of two individuals of this species with the calcareous sponge *Guadalupia* and three brachiopods.

INTRODUCTION

A REMARKABLE specimen of the calcareous sponge *Guadalupia*, from the lower Guadalupian Getaway limestone, Guadalupe Mountains, Texas, contains clear external molds of two conularias, formed as the sponge grew around their shells. The specimen is silicified and was freed from the matrix with acid. The unusual association permits certain observations to be made on the biology of both *Conularia* and the sponge. The conularia is described as *Conularia leonardensis* Finks, n. sp., based on two silicified specimens from the upper part of the Leonard formation at Split Tank, Glass Mountains, Texas. This is the first *Conularia* to be reported from the West Texas Permian, and the specimens mentioned are the only ones that have been found in the extensive collections of acid-digested silicified fossils at the American Museum of Natural History and at the United States National Museum. The large

EXPLANATION OF PLATE 82

FIGS. *1*, *2*, *4*, *5*, *11–13*—*Guadalupia* sp. with molds of *Conularia leonardensis* Finks, n. sp., and attached brachiopod shells. AMNH 27950, Getaway limestone member of Cherry Canyon formation, Guadalupe Mountains, Texas, AMNH locality 512. *1*, Incurrent surface of "ear-shaped lobe" with smaller *Conularia* mold at lower right; open *Meekella* valve above it shows overgrowth by sponge at top, ×2. *2*, View into apertural end along axis of smaller *Conularia* mold, showing two *Meekella* shells above it; productid shell at upper left overhung by "upbent lobe" and partly overgrown by sponge (arrow), ×2. *4*, View of left side of fig. *5*, "upbent lobe" at left, "ear-shaped lobe" in center; axes of the two *Conularia* molds indicated by dashed arrows, both approximately in plane of paper; position of productid shell shown by arrow, ×2. *5*, Excurrent surface of sponge looking into apertural end approximately along axis of larger *Conularia* mold (lower right); "ear-shaped lobe" of sponge in center with axis of smaller *Conularia* mold indicated by dashed arrow (actually directed about 20° above plane of paper), ×2. *11*, Incurrent surface of sponge with "upbent lobe" at top, small black square in center is lower end of smaller *Conularia* mold (axis perpendicular to paper), larger mold at bottom with dashed arrow indicating axis directed obliquely below plane of paper, ×2. *12*, Side of larger *Conularia* mold showing absence of parietal line, aperture toward right, ×6. *13*, Side of smaller *Conularia* mold, aperture toward top; note absence of parietal line but discontinuity of ribs in midline, ×6. (p. 834)

3, *6*, *7*, *10*—*Conularia leonardensis* Finks, n. sp., paratype, USNM 124422, upper Leonard formation, Split Tank, Glass Mountains, Texas, USNM locality 702a. *3*, Profile of side of steinkern viewed from apertural end, showing medial projections on ribs, overhanging mold of internal carina; rough surface apparently due to coarse silicification, ×6. *6*, Steinkern, corner groove in middle with spinose projections of ribs well shown on side to right, ×3. *7*, Full view of side at right in fig. *6*, showing groove of medial internal carina to right of "spines" in upper half of specimen and to left in lower half; condition in lower half is anomalous, as is interruption in groove at point of change, ×3. *10*, External mold of same specimen in encrusting bryozoan, showing no indication of parietal line or of "spines," ×2. (p. 834)

8, *9*—*Conularia leonardensis* Finks, n. sp., holotype, USNM 124421, upper Leonard formation, Split Tank, Glass Mountains, Texas, USNM locality 702ent. *8*, Side of steinkern, showing groove of medial carina and "spines" to left of it; upper half of right side is covered by an encrusting bryozoan; note profile view of "spines" just below bryozoan, ×3. *9*, Bent apex of same steinkern, opposite side, showing possible indication of attachment, ×6. (p. 834)

West Texas Permian collections of the United States Geological Survey include but two poorly preserved specimens of *Conularia*. Both are from the Leonardian Bone Spring limestone, and one can be referred to the species established here. Conulariids are thus notably rare in the Permian of West Texas.

The writer expresses his thanks to Professor Norman D. Newell of Columbia University and the American Museum of Natural History, and to Dr. G. Arthur Cooper of the United States National Museum, for permission and facilities to study the specimens, and for a critical reading of the manuscript. Dr. James Steele Williams made available the specimens in the collections of the United States Geological Survey. The writer has also profited greatly from discussions with Dr. J. Brookes Knight of the United States National Museum.

The Conularia-*sponge association*.—The two *Conularia* molds are part of the body of the sponge and were formed as the sponge grew around their shells. The sponge has also overgrown shells of two small individuals of the brachiopod *Meekella skenoides* Girty, and a small productid, which are preserved as siliceous replacement. The *Meekella* shells were attached to the smaller of the two conularias. The productid rests partly upon the dorsal valve of one *Meekella* and partly upon the adjacent surface of the sponge. The dorsal valves have been lost from both the productid and the other *Meekella*, and the sponge has overgrown part of the interior surfaces of the remaining ventral valves. Small patches of an encrusting bryozoan cover parts of the brachiopods and the sponge.

The sponge itself is in the form of an irregularly curved lobate sheet, one side of which bears the incurrent pores and the other side the excurrent pores. The main part of the sponge is wrapped around the larger of the two conularias, with the incurrent surface against the conularia so that the excurrent surface is convex outward. One end of this main sheet bends at a right angle and is prolonged for some distance in the direction of the excurrent side. Parallel to this extension, and arising from the middle of the excurrent surface of the main part of the sponge, is a separate lobe which is wrapped around the smaller conularia. This lobe, in which again the excurrent surface is on the convex side, is narrow near its origin, but soon develops into an ear-shaped expansion, whose concave incurrent surface is molded around the three brachiopods as well as around the smaller conularia. It fuses at one point with the bent extension of the main frond. The dorsal sides of the brachiopods face in the same direction as the apertural end of the smaller conularia, and is approximately the same direction in which the excurrent surface of the main sheet of the sponge faces. (See Pl. 82, figs. 1, 2, 4, 5, 11–13).

The history of this fossil association, as deduced from the spatial relationships of the organisms, may be summarized as follows.

1. The sponge overgrew one side of the larger conularia, simultaneously surrounding the base of the smaller conularia, and ultimately producing the ear-shaped lobe about it.

2. Two *Meekella* larvae settled together on one side of the smaller conularia and commenced to grow.

3. An ear-shaped lobe of the sponge, in continuing its growth, surrounded the two *Meekella* shells.

4. The two meekellas ultimately died, one of them losing the dorsal valve, either at this time or subsequently.

5. A productid larva settled on the closed dorsal valve of one of the dead meekellas, eventually extending its spines over the adjacent surfaces of both the ear-shaped lobe of the sponge and the upbent lobe of the main frond.

6. The productid died and its dorsal valve was swept away and lost.

7. The ear-shaped lobe of the sponge completed its growth, covering small parts of the insides of the open ventral valves of the *Meekella* and the productid, and fusing with the upbent lobe of the main frond. The upbent lobe also overgrew a small part of the interior of the productid shell. The small *Conularia* shell was probably still present at this time, as its mold extends to the very edge of the ear-shaped lobe.

8. Bryozoan colonies overgrew the exposed interior of the open *Meekella* and the

adjacent surface of the sponge, as well as the outside of both valves of the closed *Meekella* and the spines of the productid which rest on them.

On the basis of the evidence at hand, the relative time at which the sponge began to develop cannot be determined, save that its growth was nearly completed when the productid extended its spines over the ear-shaped lobe. Inasmuch as it grew relatively little during and after the lifetime of the productid, it seems that the sponge was established before the *Meekella* brachiopods had appeared, as described in the sequence of events listed above, and served as a partial support for the developing *Meekella* shells, growing simultaneously with them.

Longevity of the sponge.—The sponge was almost certainly longer lived than the productid, and probably outlived the preceding generation of the two *Meekella* individuals as well. Translation of this into terms of absolute time is speculative, but the rough order of magnitude may be suggested. Assuming that the brachiopods had a limited breeding season, as do most Recent marine invertebrates, the lifetime of the sponge must have included at least two seasons, one for the two meekellas and a succeeding one for the productid. If the two species of brachiopods bred at approximately the same time of year, then the sponge must have lived for considerably more than a year. Inasmuch as the present specimen is less than half the size of average individuals of the species at this locality, the majority of the sponges may have lived for much more than two years.

To extend this speculation farther, we might apply to the present specimens the figures obtained by Percival (1944, p. 5) for the growth rate of the brachiopod *Terebratella inconspicua* Sowerby, in the harbor at Lyttleton, New Zealand. These appear to be the only published data on brachiopod growth rates. Percival estimated the annual increment in length of his brachiopods as approximately 3.5 mm. On this basis, the *Meekella* individual represented by the closed shell, which is 7 mm. long, lived for about two years, and the overgrowing productid, which is 5 mm. long, lived for about a year and a half. This would give the sponge a life span possibly greater than three and a half years, and the average individual of the species a span greater than seven.

Individuals of many species of Recent sponges appear to attain ages in excess of twenty years, if external conditions remain favorable. On the other hand, some species inhabiting the near-shore zone of temperate waters are generally restricted to an annual life cycle by the cold of winter (Orton, 1914, p. 315; Arndt, 1928, pp. 23–24; Crawshay, 1939, pp. 565, 570; Burton, 1949, p. 914; De Laubenfels, 1952, p. 388). Presumably the environmental conditions at this Permian locality were constant enough to have permitted the majority of the sponge individuals to live for several years.

Biology of Conularia.— If we assume that the excurrent surface of the sponge faced approximately upwards, then the apertures of the two individuals of *Conularia* faced obliquely upwards with their axes about 70° apart. They are, furthermore, so disposed that the apex of the smaller individual must have been attached to a corner edge of the larger. Their upright orientation while being overgrown by the sponge suggests that they were sessile,[1] and supports similar conclusions which have long since been drawn for some species of *Conularia* from anchoring structures at the shell apex. A possible apical attachment scar is visible on the specimen USNM 124421 of the present species (Pl. 82, fig. 9). The spatial relationships of the two individuals suggest that the smaller may be a bud. Groups of conulariids attached together have been observed before and it has been suggested that they were colonies formed by budding (Termier & Termier, 1948, pp. 717 ff.). If budding does

[1] Since this paper was sent to press the writer has encountered a specimen which provides further evidence. A small, bun-shaped lithistid sponge was found to include external molds of two individuals of *Conularia* cf. *C. leonardensis*, oriented approximately perpendicular to the sponge surface. The apices are enclosed within the sponge. This suggests that the sponge grew around the conularias after they had settled on its surface. Specimen is from base of Bone Spring limestone, near top of northernmost hill on east side of Black John Canyon, Sierra Diablo, 2.9 miles WNW of BM 3585, Figure Two Ranch, Van Horn Quadrangle, Texas. Princeton University, S. J. Kříž collection, courtesy of Dr. B. F. Howell.

take place, the conulariids can not, of course, be pteropods, as has sometimes been assumed, but it would not be inconsistent with their being scyphozoans (Kiderlen, 1937) or protochordates (Termier & Termier, 1948).

Paleontologists have generally agreed that the conulariid shell must have been flexible and elastic. This has been assumed from its thinness, its chitinophosphatic composition, the absence of hinge structures on the extensions of the sides that close over the aperture, and the fact that the shells have been found with the sides bent in without any signs of fracturing (Kiderlen, 1937, p. 119; Termier & Termier, 1948, p. 716). Whether movement of the shell, apart from the apertural flaps, was necessary for the life of the animal is not known. The sharp external molds of the present individuals imply a lack of movement, and indeed the rigidity of the enclosing sponge would have effectively prevented it, for available evidence indicates that this type of sponge was an essentially rigid body. Therefore, either these individuals were dead before they were overgrown, or else flexible movement was not necessary to them.

SYSTEMATIC DESCRIPTION

CONULARIA LEONARDENSIS Finks, n. sp.
Pl. 82, figs. 1–13

Shell small and narrow with apical angle of about 8°–10°; cross section square with slightly bowed-out sides; cross ribs arched gently toward aperture, not sharply angulated at midline and usually opposite one another on either side of it; ribs, on steinkern, represented by narrow, smooth, flat-topped ridges 0.04–0.1 mm. wide, separated by smooth concave areas twice to five times as wide; ribs wider and farther apart as shell expands, generally 7 to 9 in a longitudinal distance equal to width of shell in that region; ribs rise higher above surface of steinkern as they approach midline where they are interrupted by a continuous longitudinal groove of rounded cross section 0.1–0.2 mm. wide, probably representing the impression of an internal carina since it does not appear on external mold; median end of each rib on one side of groove (almost always the left side, orienting the aperture upwards) widens somewhat and bears a spinose projection as much as 0.3 mm. long, partly overhanging the groove; projection apparently represents filling of tubular hollow on inner surface of shell since it could not be seen on external mold; ribs alternate on opposite sides of corner groove; corner groove preserved on steinkern as very shallow smooth depression in which ribs are absent; on external mold, ribs represented by grooves, parietal line absent except as slight angulation in rib grooves, corner groove obscure, no fine surface ornamentation clearly preserved.

Measurements (all in mm.):

Specimen	Length preserved	Range of width	Apical angle (computed)	Spacing of ribs
USNM 124421 (holotype)	24	1.0–5.0	9° 32′	0.15–0.6
USNM 124422 (paratype)	15	2.5–5.0	9° 32′	0.4 –0.7
AMNH 27950:				
small mold	17	1.5–4.0	8° 24′	0.3 –0.4
large mold	7	3.0–4.0	8° 10′	0.4

Discussion.—This species is distinguished, so far as the specimens are preserved, by its small size and narrow apical angle, its square cross section, its narrow, gently arched ribs separated by wide interspaces, its lack of a parietal line on the exterior, its shallow corner grooves lacking rib impressions or internal strengthening, and its short internal carina at the midline of each face. The peculiar row of spines along the midline of each face on the steinkern presumably represents a row of depressions on the inner surface of the shell. It has not been described elsewhere, to the writer's knowledge, and its significance is unknown. The regularity of the disposition of the spines on the same side of the internal carina of each face is noteworthy. The single exception to

this rule, on the lower part of one side of USNM 124422, only strengthens the impression of regularity, since it is the internal carina which is interrupted and changed in position, while the spines continue in an unbroken row (Pl. 82, fig. 7).

The two type specimens from the upper Leonard of the Glass Mountains (USNM 124421, USNM 124422) are silicified steinkerns, each accompanied by a partial external mold in an overgrowing bryozoan. The apical end of the holotype appears to be nearly complete; it is bent and bears irregular depressions which may be related to an apical attachment, though it is by no means clear (Pl. 82, fig. 9). The apertural end is not preserved on either specimen.

The two external molds in the sponge (AMNH 27950) are from a higher horizon, the lower Guadalupian Getaway limestone of the Guadalupe Mountains. They appear to be similar to the types, so far as they can be compared, but the following differences are to be noted: (1) the ribs of the smaller mold are not always exactly opposite one another on either side of the midline (Pl. 82, fig. 13); (2) there are traces of possible small tubercles on the ribs, 0.05 mm. in diameter and 0.20–0.23 mm. apart; and (3) the apical angle is somewhat smaller, being about 8°. These variations are hard to assess, because of the paucity of material and the differences in preservation. The value for the apical angle, computed trigonometrically from the widths of the two ends of the specimens, is possibly less accurate for the molds in the sponge than for the types, because of mechanical difficulties of measurement.

It should also be noted that the paratype has slightly more widely spaced ribs, at comparable diameters, than either the holotype or the two molds in the sponge. The last three are identical in this respect.

There are two specimens of *Conularia* in the West Texas Permian collections of the United States Geological Survey, both calcified and rather poorly preserved. One of them, from USGS locality 6668A, Bone Spring formation (Leonardian), top of section at Apache Canyon, Sierra Diablo, Van Horn Quadrangle, appears to be identical to the type material. The other specimen, from USGS locality 7726, lower Bone Spring limestone, south bank of first canyon north of Bone Canyon, 0.4 mile north of Williams Ranch, Guadalupe Peak Quadrangle, is similar but too fragmentary to identify with certainty.

Only two conulariids have previously been reported from the Permian of the western hemisphere: *Conularia kaibabensis* McKee, 1935, from the Kaibab limestone of Arizona, and *Conularia* sp. (Girty, 1910, page 20) from the Phosphoria ("Park City") formation of Idaho. The Phosphoria species is represented by one incomplete specimen which is too poorly preserved to compare in detail. It is recognizably different from the present species in having a wider apical angle (about 17°), and in having somewhat more closely spaced ribs. *C. kaibabensis* agrees with the present species in the unusually small apical angle but is much larger and does not agree with any of its other distinguishing features.

Conularia simplicosta Grabau, 1924, from the uppermost middle Permian Peichien formation of Hupeh, China, also resembles the present form in apical angle (computed by the writer at 6° 20′ from Grabau's statement [1924, page 482] that "The shell tapers at the rate of 1.10 millimeters in 10 millimeters") and in its small size, never being wider than 4 mm. It differs in that the ribs are "straight," which I presume means not bowed aperturally, though this condition is approached on the larger mold in the sponge, and in that the ribs are twice as closely spaced. Unfortunately, Grabau published no illustrations, and the brief written description permits of no further comparison.

Of the other Permian conulariids in the literature, perhaps the closest are the specimens from Australia described by Fletcher (1938, p. 247) as *Conularia laevigata* Morris. The Australian specimens differ from typical members of *C. laevigata* in having a square cross section like the present species.

The sponge is a new species of *Guadalupia* Girty and will be described by the writer in a comprehensive study of the sponge fauna of the Texas Permian.

Types and localities.—Holotype, USNM 124421, USNM locality 702ent, upper Leonard formation (original Leonard of P. B. King), slopes on south side of road 0.2–0.5

mile east of Split Tank, 1½ miles NE of road fork near old Word ranch, about 19 miles NNE of Marathon, Hess Canyon Quadrangle, Texas.

Paratype, USNM 124422, USNM locality 702a, upper Leonard formation (middle of P. B. King's original Leonard formation) ½ mile east of Split Tank, 19 miles NNE of Marathon, Hess Canyon Quadrangle, Texas.

Molds in *Guadalupia*, AMNH 27950, AMNH locality 512, Getaway limestone member of Cherry Canyon formation, at break in slope near crest of promontory approximately ¼ mile due south of U. S. Highway 62, BM 5426, Guadalupe Mountains, Texas.

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ADDITIONAL NEW ORDOVICIAN GRAPTOLITES AND A CHITINOZOAN FROM OKLAHOMA

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ABSTRACT—Graptolites have been isolated from lower Viola limestone (middle Mohawkian) by dissolving a block of it in acid. Fragments of *Leptograptus?* show that the development is of dicellograptid type, and that th 1^2 has an initially upward direction of growth. *Pipiograptus hesperus*, n. gen., n. sp., has sicula, initial bud, and proximal part of first three thecae with continuous periderm, remainder of scandent, biserial rhabdosome represented by a clathria. Thecae alternating, first and second hook-shaped, third and fourth with straight ventral walls, little overlap between them. Apertural spines, and spines on ventral and lateral walls, some forked. Development of non-septate diplograptid type. *Pipiograptus*, n. gen., is placed in the Diplograptidae. *Phormograptus sooneri*, n. gen., n. sp., has sicula and proximal portion of initial bud only with continuous periderm, remainder of scandent, biserial rhabdosome a reticula supported by a clathria; clathria includes virgella spine, apertural spines of sicula, median ventral lists of thecae, and cross-bars, with virgula as central strand; reticula attached to tips of clathria. Thecal apertures introverted. Development of diplograptid type. *Phormograptus*, n. gen., is placed in in the Retiolitidae. Associated with the graptolites are tiny, elongate sacs, here referred with question to the chitinozoan *Rhabdochitina*.

INTRODUCTION

SINCE preparing the description of *Orthoretiolites* (Whittington, 1954) I have dissolved serveral more pounds of limestone and, using the same techniques, continued to obtain specimens from the lower Viola limestone (see list below). The graptolites described here are among the rarest. Though the material of each species is far from adequate, that of the two retiolitids (using this term with a morphological rather than a taxonomic connotation) is sufficient to reveal important features of the proximal part of the rhabdosome. Few Ordovician retiolitids have been recovered, so that these new finds add to our knowledge, though they by no means simplify the picture of retiolitid phylogeny. The fragments of *Leptograptus?* reveal details of the proximal end of the rhabdosome for the first time. The terminology of description is that employed by Bulman (1938), and the special terms used for retiolitids were discussed previously (Whittington, 1954). The commonly occurring chitinozoan is also described. The specimens are in the collection of the Museum of Comparative Zoology (abbreviated as MCZ).

Dr. O. M. B. Bulman has maintained a friendly interest in this work, and kindly read the manuscript critically. I am indebted to Miss Pat Washer for her skill and patience in preparing the text-figures from my pencil sketches.

Locality, fauna, and geological horizon.—The finely granular, light grey-brown limestones which yielded the graptolites were collected from 100 feet above the base of the Viola limestone, in a road cut on U. S. Highway 77, centre of the E½ sec. 25, T. 2 S, R. 1 E., Carter county, and 2½ miles north of Springer, Oklahoma. Trilobites found here include *Cryptolithoides ulrichi* Whittington, 1941, *Robergia deckeri* Cooper, 1953, *Hypodicranotus* sp., *Trinodus* sp., and an asaphid. These suggest a late Black River or early Trentonian age. A revised list of graptolites yielded by dissolving the limestones is as follows:

Leptograptus? sp. ind.	7
Dicranograptus cf. *nicholsoni* Hopkinson, 1870	9
Cryptograptus sp.	6
Orthograptus sp.	15
Climacograptus aff. *C. typicalis* Hall, 1865.	200 ±
Climacograptus spp.	11
Orthoretiolites hami Whittington, 1954	34
Pipiograptus hesperus n. gen., n. sp.	9
Phormograptus sooneri n. gen., n. sp.	11

The figures are numbers of specimens well enough preserved to be picked out of the residue and retained, and give an idea of frequency of occurrence. There are additional

indeterminable fragments, and the chitinozoan is common. The rare graptolites occur sporadically, e.g., all the specimens of *Cryptograptus*, and the best of *Leptograptus?* came from the first few fragments dissolved. The new retiolitids are not only rare but delicate and difficult to mount, so that the number of specimens is added to extremely slowly.

SYSTEMATIC PALEONTOLOGY

GRAPTOLOIDEA Lapworth, 1875

?Family LEPTOGRAPTIDAE Lapworth, 1879

? Genus LEPTOGRAPTUS Lapworth, 1873

LEPTOGRAPTUS? sp. ind.

Pl. 83, figs. 1, 2; text-figs. 1–5

Material.—Three translucent fragments of the proximal end, two fragments of stipes. MCZ 520a–e, from the lower Viola limestone, Middle Mohawkian.

Description.—Length of preserved portion of metasicula, width at aperture, in millimetres, of MCZ 520a, 1.3, 0.22; MCZ 520b, —, 0.2; MCZ 520c, 1.18, 0.2; length virgella spine of MCZ 520a, 0.7 mm.

Rhabdosome with long, slim sicula, in MCZ 520c original length about 1.7 mm., 0.2 mm. wide at aperture, long virgella spine; stipes diverge at 180° and distally curve gently upwards, in MCZ 520d (Pl. 83, fig. 1,) first four thecae in 3.25 mm., i.e. about 12 thecae in 10 mm.; maximum width of stipe (MCZ 520d) 0.46 mm. at first thecae, 0.52 mm. at fourth; thecae with aperture introverted by growth of inwardly directed ventral lip, which is faintly bifurcated, apertural excavation with thickened, projecting distal edge, stout mesial spines on first three thecae.

Development.—Text-figures. 1–3, 5 show the translucent specimens of the proximal end, and growth lines have been drawn wherever they could be observed. The virgella is present at an early stage in the growth of the metasicula, rapidly lengthens, and there is a virgella spine after about half the maximum size is reached (Text-fig. 5). The initial bud emerges from a foramen situated against the obverse margin of the virgella at about three-quarters the length of the sicula, and th 1^1 grows down the wall of the sicula, as a hood, to the margin. Here it turns abruptly and, in the form of a tube, is directed outward and slightly downward. Growth lines show that the aperture of this distal part is directed slightly upward, and at the extremity, with the growth of the mesial spine and ventral lip (which is lobate and extends around the lateral margins of the aperture) it is directed upward almost at right angles. Th 1^2 (Text-figs. 1, 3) emerges from a foramen on the reverse lateral wall of the initial bud, and is at first directed upward and inward (Text-fig. 3). Shortly it curves around to cross the virgella horizontally, then is directed downward and outward across the reverse sicular wall. Just before the margin is reached it turns outward horizontally. Th 2^1 (Text-figs. 1, 3) emerges on the virgella side of the earliest downwardly directed part of th 1^2, grows at first outward and slightly down (Text-fig. 3, with growth lines on the inner side indicated by broken lines), then more directly down before turning abruptly to grow out along the dorsal side of th 1^1. Th 2^2 (Text-figs. 1, 3, 5) emerges from the ventral wall of the initial portion of th 2^1 and grows slightly downward across the

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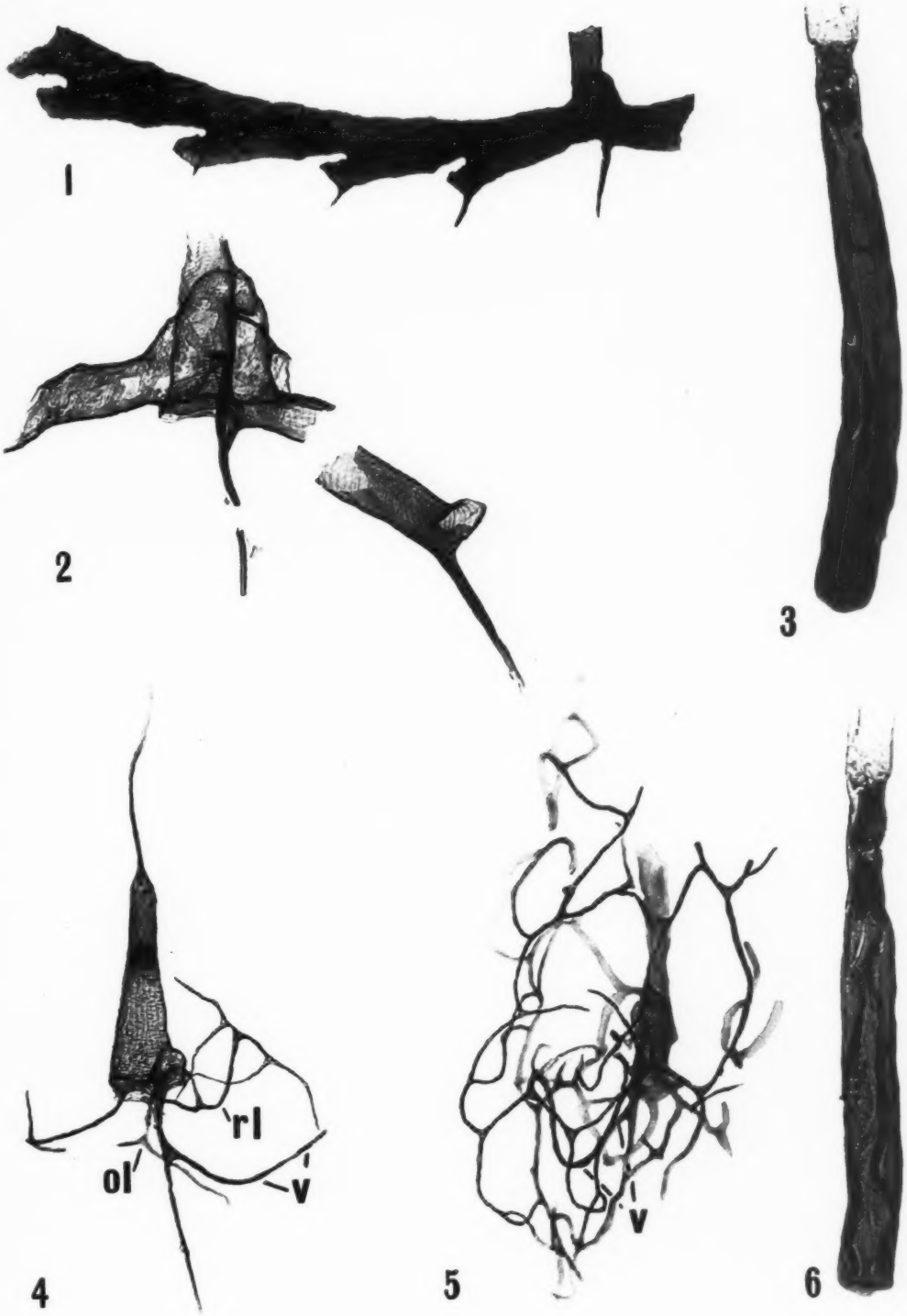
EXPLANATION OF PLATE 83

FIGS. *1, 2—Leptograptus?* sp. indet. *1*, proximal portion of rhabdosome, reverse view. MCZ 520d, ×24. *2*, reverse view of damaged translucent specimen, th 1^1 complete, next three thecae in progressively earlier stages of development. Compare Text-fig. 3. MCZ 520 b, ×49.

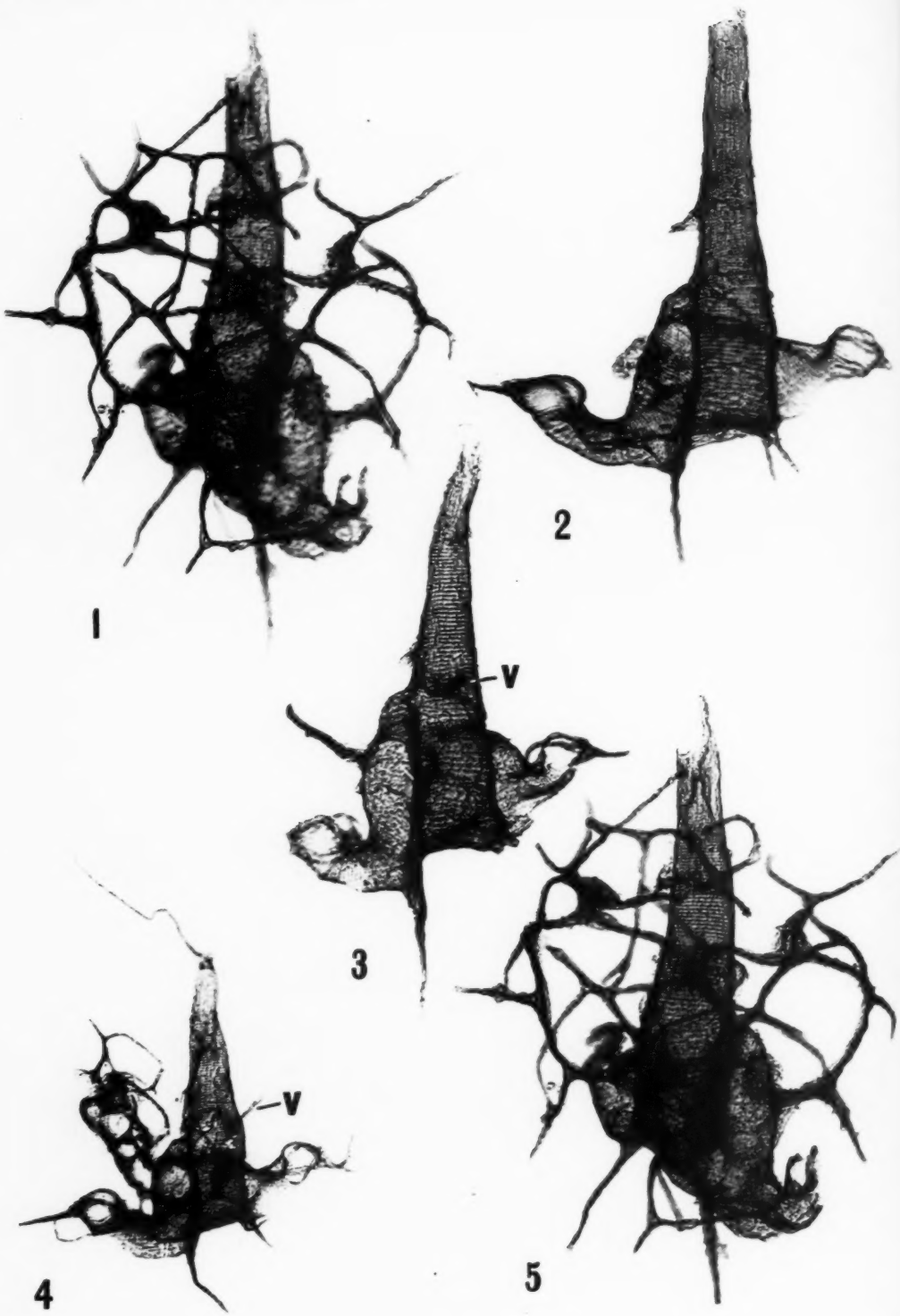
3, 6—Rhabdochitina? cf. *R. minnesotensis* Stauffer. MCZ 1021, ×78.

4, 5—Phormograptus sooneri Whittington, n. gen., n. sp. *4*, reverse view, clathria of th 1^1 incomplete. MCZ 524e, ×49. *5*, sub-scalariform view of part of first stipe of incomplete specimen. MCZ 524c, ×49. v = ventral list of th 1^1; rl = reverse lateral thread of reticula; ol = obverse lateral thread of reticula.

All from Viola limestone, 100 feet above base, road cut on U. S. Highway 77, 2½ miles north of Springer, Oklahoma. Photographed in infra-red light.



Whittington, Oklahoma Ordovician graptolites and chitinozoan



Whittington, Oklahoma Ordovician graptolites

virgella before turning upward to cross over to the dorsal wall of th 1^2. MCZ 520d is opaque in ordinary light, but in infra-red light (Pl. 83, fig. 1) a darker band reveals the line of overlap between successive thecae, and indicates their points of origin. There is a faint projection of the dorsal wall at the beginning of each theca.

From the above information the thecal diagram (Text-fig. 4) has been constructed.

Discussion.—This material is placed in *Leptograptus?* because of the long, slender sicula, relatively low angle of divergence of the stipes, and introversion, but not introtortion, of the aperture. It is evidently like some species of *Dicellograptus*, e.g. *D. geniculatus* Bulman (1932a, pp. 19–21, pl. 7, figs. 9–13, text-fig. 6), differing from this particular species notably in the much longer sicula and lower angle of divergence of the stipes. Further, the development is of dicellograptid type (Bulman, 1932b, p. 9, but in 1936, p. 6 referred to it as the *geniculatus* stage of the Leptograptid type), with three crossing canals. Bulman's 1947 (Test-fig. B) thecal diagram of *Dicellograptus geniculatus* differs from his earlier versions (e.g., 1932b, pl. I, fig. e., pl. II, fig. a) in that an upward curvature is given to the initial portion of th 1^2, making this diagram almost identical with that given here for *Leptograptus*. Thus it seems that these specimens might almost equally well be placed in *Dicellograptus* as in *Leptograptus*.

The most significant feature shown by the present material is the initially upward growth of th 1^2 and its subsequent downward curvature. This feature, combined with the direction of growth of the other thecae, gives the thecal diagram of the proximal portion of *Leptograptus?* (Text-fig. 4) a close resemblance not only to that of *Dicellograptus* but also to those of *Glyptograptus dentatus*, *Dicranograptus nicholsoni*, and various other biserial graptolites (see Bulman, 1947, pp. iv–xi, text-figs. B, C).

Family DIPLOGRAPTIDAE Lapworth, 1873
Genus PIPIOGRAPTUS Whittington, n. gen.

Type species.—*Pipiograptus hesperus* Whittington, n. gen., n. sp.

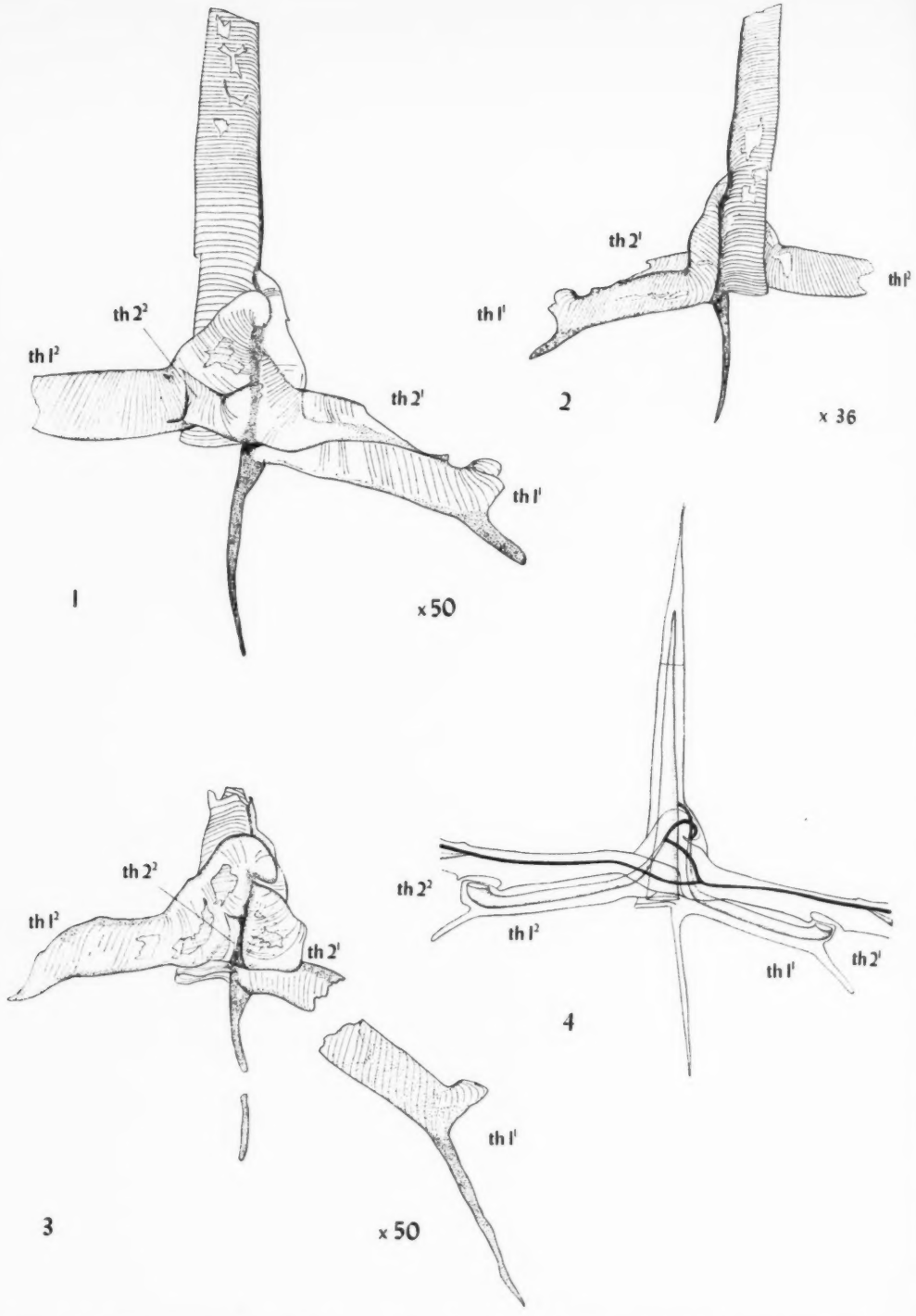
Diagnosis.—Sicula, initial bud and proximal part only of th 1^1, th 1^2 and th 2^1 with continuous periderm, remainder of biserial scandent rhabdosome represented by a clathria. Thecae alternating, first and second hook-shaped, third and fourth with straight ventral wall, little overlap between successive thecae. Forked apertural spines, and numerous spines, some forked, on ventral and lateral walls. Development of non-septate diplograptid type.

Discussion.—Only the first four thecae of this species are known, hence the diagnosis is necessarily incomplete. *Pipiograptus* is like *Orthoretiolites* (Whittington, 1954) but is distinguished from it principally by the following characters: a) the sicula is slimmer, the width of the metasicula at the aperture being one-third or less of the length, rather than almost one-half; b) th 1^1 grows farther downward, below the level of the sicular aperture, before turning outward; c) both th 1^1 and th 1^2 are relatively longer, more strongly curved, and with continuous periderm extending farther distally; d) the ventral lists of th 2^1 and th 2^2 arise closer to the sicula, and hence the

EXPLANATION OF PLATE 84

FIGS. *1–5*—*Pipiograptus hesperus* Whittington, n. gen., n. sp. Viola limestone, 100 feet above base, road cut on U. S. Highway 77, 2½ miles north of Springer, Oklahoma. *1, 5*, holotype, reverse views, focussed on nearest part of clathria and on reverse wall of sicula respectively. Compare Text-fig. 12. MCZ 521. ×78. *2*, obverse view, th 1^1 and th 1^2 complete. Compare Text-figure 7. MCZ 522b. ×78. *3*, obverse view, th 1^1 and th 1^2 complete, th 2^1 and th 2^2 slightly more advanced than in fig. 2. v = base of obverse ventral list of th 2^2. Compare Text-fig. 8. MCZ 522d. ×78. *4*, obverse view, sicula, virgula, th 1^1 and th 1^2 complete, th 2^1 damaged. v = incomplete obverse ventral list of th 2^2. Compare Text-fig. 9. MCZ 522e. ×49.

Photographed in infra-red light.



FIGS. *1–4—Leptograptus?* sp. indet. Growth stages and thecal diagram. *1*, *2*, th 1^1 complete, next three thecae partially grown, reverse and obverse views, MCZ 520a. *3*, th 1^1 complete but broken, second and third thecae partially grown, early stage of fourth, reverse view, MCZ 520b. Growth lines of inner side of th 2^1 shown by broken lines. *4*, Thecal diagram, showing approximate points of origin and directions of growth of first four thecae. "Common canal" in solid black.

distal parts of th 1^1 and th 1^2 are free, not overlapped; e) the clathria of th 2^1 and th 2^2 includes more lists, there are more lateral and ventral spines, and the aperture bears the forked spine and median list.

The position of the virgula in the clathria of *Pipiograptus* is unknown. However, the positions of attachment to the obverse side of the sicula of the parietal and ventral lists of th 2^1 and th 2^2 (Text-fig. 13) suggest that the virgula is close to, if it does not lie in, the obverse wall of the clathria. The thecal diagrams of *Pipiograptus* (Text-fig. 14) and *Orthoretiolites* (Whittington, 1954, Text-fig. 3) are similar, as also is the mode of development.

The characters which distinguish *Orthoretiolites* from *Archiretiolites* and *Plegmatograptus* (Whittington, 1954, p. 614) serve

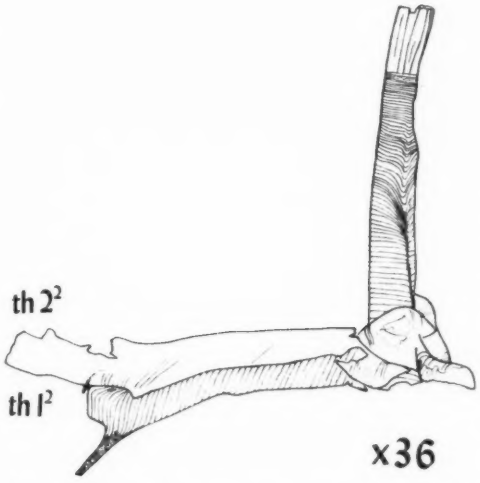


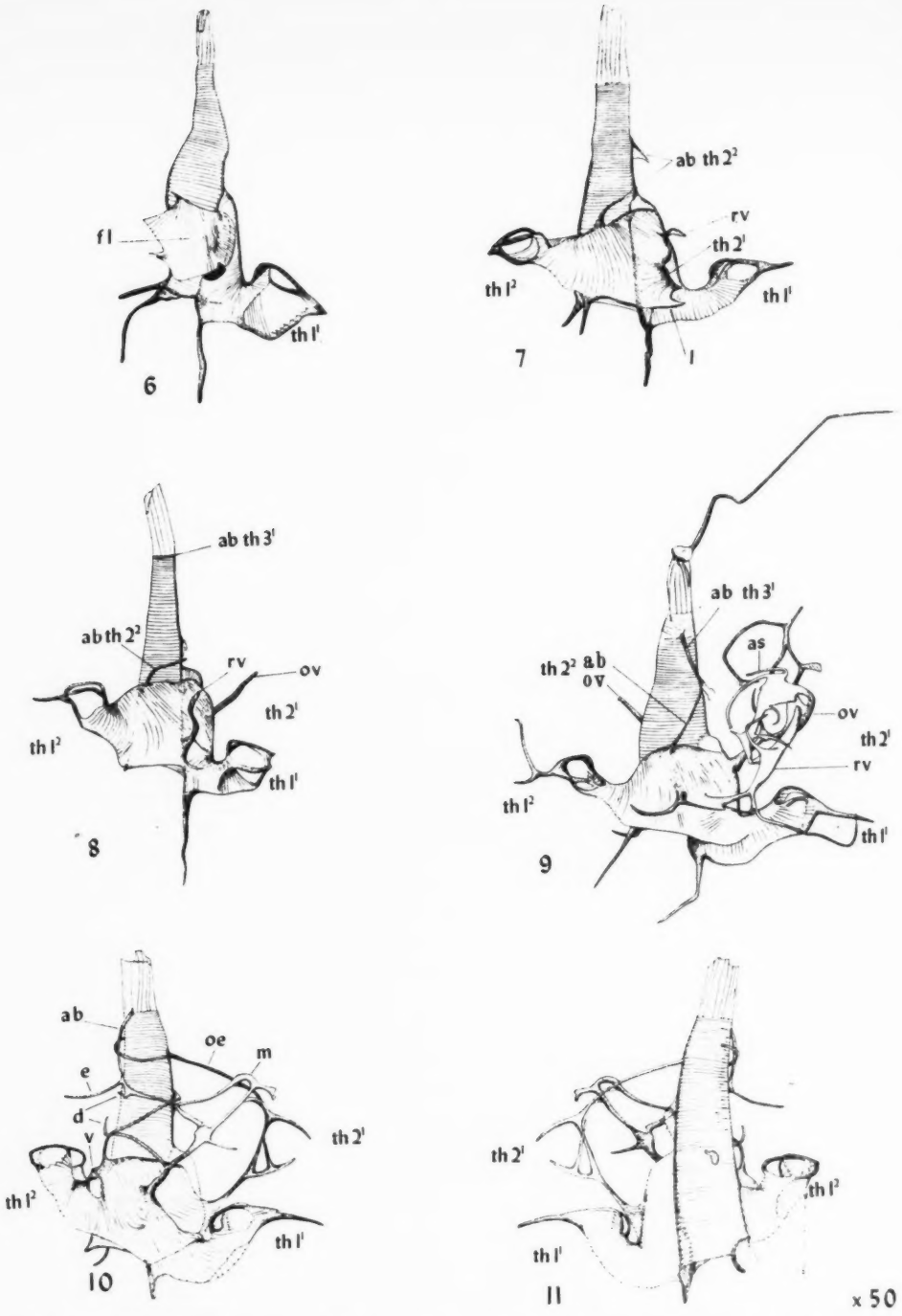
FIG. 5—*Leptograptus?* sp. indet. Broken fragment of proximal portion of rhabdosome th 1^2 complete and proximal part of the 2^2 preserved, reverse view, MCZ 520c.

equally to distinguish *Pipiograptus*. The arguments for placing *Orthoretiolites* in the Diplograptidae have been given (Whittington, 1954, p. 614). Though the shape and arrangement of the thecae of *Pipiograptus* are not orthograptid, the other lines of reasoning may be followed to suggest placing *Pipiograptus* tentatively in the same family.

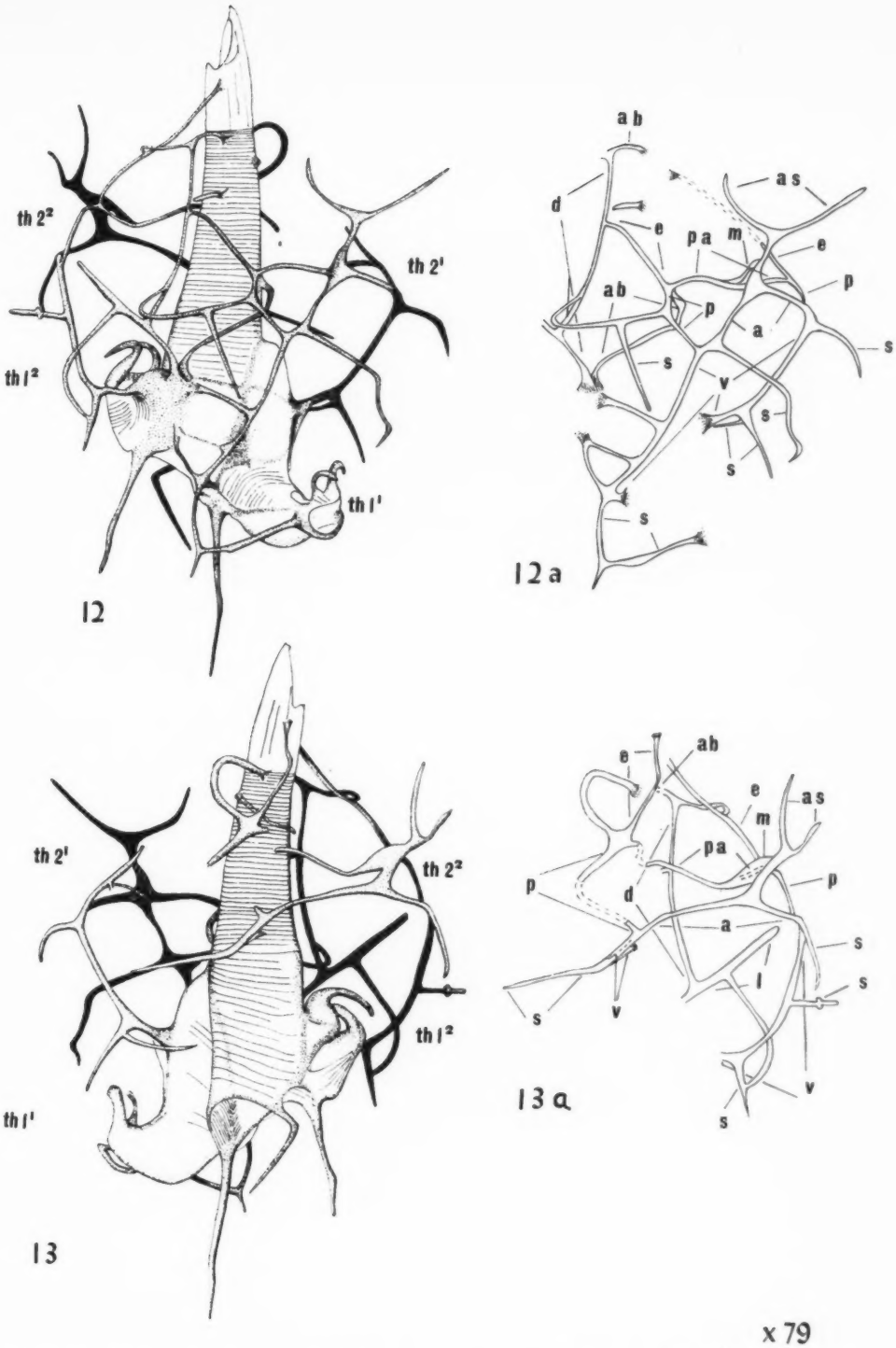
Pipiograptus hesperus Whittington, n. gen., n. sp.
Pl. 84; Text-figs. 6–14

Material.—Six specimens, holotype MCZ 521, others MCZ 522 a–e, from the lower Viola limestone, middle Mohawkian.

Description of largest rhabdosome.—Length of holotype, 1.22 mm.; metasicula of length 0.58 mm., width at aperture 0.16 mm. General appearance is shown in Pl. 84, figs. 1, 5, and Text-figs. 12, 13. Sicula with stout virgella spine and pair of apertural spines. Th 1^1 grows down the virgella side of the sicula to the base of the virgella spine and then turns outward and slightly downward, distally becoming upturned. The periderm of the proximal part of th 1^1 is continuous, in the form of a hood attached to the sicula. Immediately after it turns outward and downward the periderm appears to be continuous, of tubular form, but in the distal horizontal and upturned portions it is not continuous. Lateral walls are present, but not dorsal or ventral. Distally the inner (dorsal corners of the lateral walls are extended as hook-shaped lists; the outer (ventral) corners are also extended as lists which unite with each other. In the holotype, unlike other specimens (e.g., Text-fig. 10), because of poor preservation or other reasons, the hook-shaped lists are not extended to meet the ventral lists, nor is there an apertural spine. The distal portion of th 1^2 is of the same form and size as that of th 1^1, the obverse lateral wall attached to the antivirgella side of the sicula (Text-fig. 13). The reverse lateral wall of the proximal portion of th 1^2 is continuous with the flange, which is attached at the dorsal and ventral (upper and lower in Text-fig. 12) edges to the sicula. The flange includes the proximal portions of both th 1^2 and th 2^1, and its developmental described below. All but the most proximal portion of th 2^1 is represented by lists, interpreted here as indicated in Text-figs. 12, 12a. Ventral, apertural, post-apertural, pleural, parietal, and the reverse dorsal list outline the theca, and there are additional lists in the reverse lateral wall. Various spines (s in Text-figs. 12a) arise from the lateral spines and ventral walls, notably those at the corners of the aperture and the forked



FIGS. *6–11*—*Pipiograptus hesperus* Whittington, n. gen., n. sp. Stages of growth of first three thecae and most proximal portions of fourth and fifth thecae. *6*, reverse view, th 1^1 complete, flange (fl) representing proximal portion of th 1^2, foramen of th 1^2 solid black where visible, margin beneath flange shown by dotted line. MCZ 522a. *7*, reverse view, th 1^1 and the 1^2 complete, most proximal portions of th 2^1 and the 2^2. MCZ 522b. *8*, reverse view, th 1^1 and th 1^2 complete, th 2^1 more advanced, most proximal portions of th 2^2 and th 3^1. MCZ 522d. *9*, reverse view, flattened specimen, sicula, virgula, th 1^1 and th 1^2 complete, th 2^1 damaged, but ventral lists unusually broad, most proximal parts of third and fourth thecae. MCZ 522e. *10*, *11*, reverse and obverse views, first three thecae complete, most proximal portions of fourth and fifth. MCZ 522c. ab = aboral list; as = apertural list; d = dorsal list; e = parietal list; fl = flange; l = lower (ventral) edge of lateral wall of most proximal portion of th 2^1; m = median list; v = ventral list; o and r used as prefixes denoting obverse or reverse side of rhabdosome.



FIGS. *12, 13—Pipiograptus hesperus* Whittington, n. gen., n. sp. Holotype, MCZ 521, first four thecae complete, aboral list of fifth theca. *12*, reverse view. *12a*, outline of lists of th 2^1 with explanatory symbols. *13*, obverse view. *13a*, outline of lists of th 2^2, with explanatory symbols. a = apertural list; ab = aboral list; as = apertural spine; d = dorsal list; e = parietal list; l = lateral list; m = median list; p = pleural list; pa = post-apertural list; s = spine; v = ventral list.

apertural spine. From the base of the latter a median list (m in Text-fig. 12a; compare Pl. 84, fig. 5) runs across to the mid-point of the post-apertural list and thus divides the aperture. The obverse parietal list of th 2^1 is broken, but the missing portion is restored in Text-fig. 12a, since the list is complete in MCZ 522c (Text-fig. 11). The proximal of the transverse lists ab (the lower "ab" in Text-fig. 12a) is regarded as the aboral

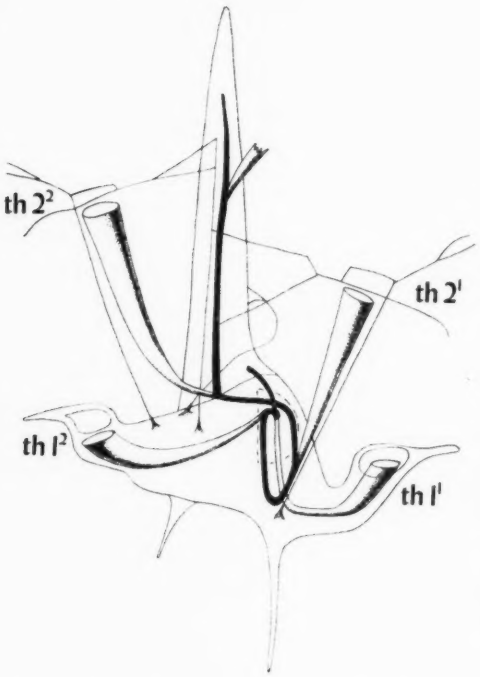


FIG. *14—Pipiograptus hesperus* Whittington, n. gen., n. sp. Thecal diagram, showing approximate points of origin and direction of growth of first five thecae. "Common canal" in solid black.

list of th 2^2, in that it approximately indicates where th 2^2 branches from the "common canal." The tuning-fork shaped spine shown at the base of Text-fig. 12a is laterally directed, one prong arising at the base of the reverse ventral list of th 2^1, the other on the lateral wall of the distal part of th 1^1, the two uniting distally. Th 2^2 (Text-figs. 13, 13a) is outlined by ventral, apertural, post-apertural, pleural and parietal lists, and is of much the same form and size as th 2^1, and has a similar forked apertural spine and median list dividing the aperture. The lists on the obverse side have been bent and broken in the flattening of the specimen, and the interpretation suggested in Text-fig. 13a is tentative. The list labelled "ab" in Text-fig. 13a (shown also at the top of Text-fig. 12a) is presumed to be the aboral list of th 3^1. There are spines on the ventral lists of th 2^2, and additional lists in the lateral walls, as there are in th 2^1.

Early Growth Stages

The originals of Text-figures 6–11 (cf. Pl. 84, figs. 2–4) show the development of the first three, and earliest part of the fourth, thecae. Dimensions of the metasicula of four specimens are as follows: MCZ 522a, 522b, 522c, 522d respectively, length 0.62, 0.58, 0.62, 0.58 mm., width at aperture 0.1, 0.18, 0.18, 0.18 mm., MCZ 522e with sicula of length 0.8 mm., width at aperture 0.2 mm., length prosicula 0.2 mm.

Sicula and first two thecae.—Prosicula about one-third as long as the metasicula with longitudinal rods. The metasicula expands gradually, the growth lines becoming more widely spaced distally. The thickening of the wall representing the virgella is present after about one-fifth the length, and at the margin the walls are drawn out beside the base of the long virgella spine. On the opposite side the thickened margin is deeply excavated between the apertural spines. The initial bud emerges at about half the length of the metasicula and grows downward as a hood, the margins of which are attached to the wall of the sicula. Where it becomes free th 1^1 assumes a tubular form, the margins of the tube attached to the blade-like base of the virgella. Here (below the level of the sicular aperture) th 1^1 turns abruptly outward and is directed horizontally. The distal portion continues the curving course and becomes almost vertical, but only the lateral walls are represented by continuous periderm (Text-figs. 6–8). As the aperture is approached the dorsal and ventral edges of these walls are thickened, and the latter are extended as lists which unite to form a single median ventral list. The dorsal edges of the lateral walls are extended as separate lists which curve upward, circumscribe the aper-

ture as pleural lists and unite with the ventral list. From this junction a single apertural spine arises, giving the distal part of th 1^1 its typical "bird's-head" appearance. In some specimens this apertural spine (or that of th 1^2) is missing, but in others (Text-fig. 9) it may be bifid or even trifid. Shreds of translucent periderm lie inside the dorsal and ventral lists, growth lines appearing as darker lines (Text-figs. 6, 7, 9).

The foramen of th 1^2 (Text-fig. 6; also outlined as a lighter area in Pl. 84, figs. 2, 4) is large, elongated, one side bounded by the wall of the sicula. The earliest known stage of development of the second theca is shown in Text-fig. 6. It is in the form of a flange of periderm, attached outside the edge of the foramen to the reverse lateral wall of the initial bud and early part of th 1^1, and along the upper margin to the reverse wall of the sicula. The main part of the flange hangs down a short distance away from these walls, partly concealing the foramen of th 1^2, the lower edge free. The position and growth-lines of the flange suggest that the earliest-formed part is that high up on the wall of the initial bud, and thus that th 1^2 at first grows slightly upward from the foramen before turning abruptly downward and outward. In the original of text-figure 7 th 1^2 is complete, and shows that the flange grows downward and apparently unites with the margin of the sicula near the base of the virgella. By the time the flange has grown as far as the antivirgella side of the sicula its direction of growth is horizontal, and at about this stage th 1^2 is sheathed in a tube of periderm, the obverse side attached to the wall of the sicula above the apertural notch. The succeeding free, distal part of th 1^2 is like that of th 1^1, curving upward, the lateral walls only of continuous periderm which passes into the dorsal and ventral lists.

Third theca.—The initial portion of th 2^1 is shown by the originals of Text-figs. 7, 8. It is in the form of a small sheet of periderm growing downward and outward from the early-formed part of the flange across the lower part of the foramen. The lower edge (1 in Text-fig. 7) is attached to the reverse lateral wall of th 1^1, but the distal and dorsal edges are free, and lie a short distance away from the reverse lateral wall of th 1^1. The reverse ventral list of th 2^1 (rv in Text-figs. 7, 8) arises from the early-formed part of the flange, and the obverse ventral list of the 2^1 is attached to the obverse lateral wall of th 1^1. Evidently th 2^1 grows at first downward and slightly outward, emerging from beneath the flange beside the proximal portion of th 1^1, and then turning abruptly upward and outward. The original of Text-fig. 8 shows the margin of the flange from beneath which th 2^1 emerges, and this margin, together with the distal edge of the continuous periderm of th 2^1, are shown by the holotype (Pl. 84, fig. 5). In the original of Text-fig. 10 the main lists of th 2^1 are complete-ventral, apertural, post-apertural, pleural and parietal (compare lettering of Text-fig. 12a with Text-fig. 10)—except for the dorsal, the early-formed portions of which are indicated. The median apertural list is well shown (m in Text-fig. 10) but the apertural spine is broken off at the base. Spines on the ventral lists are complete, but comparison with Text-fig. 12 shows that lists in the reverse lateral wall, and the tuning-fork shaped lateral spine, are not yet developed. The continuous periderm of the proximal part of the reverse lateral wall is more extensive than at an earlier stage (Text-figs. 7, 8), attached at the lower edge to the free tubular portion of th 1^1. The original of Text-fig. 9 is flattened, and some of the lists of th 2^1 apparently broken and incomplete. The ventral and apertural lists are unusually broad, having a fibrous appearance in transmitted light, and revealing growth lines in the photograph (Pl. 84, fig. 4). Bifurcating lateral spines arise from the reverse ventral list of th 2^1 and the flange, and apparently have counterparts, slightly differently constructed, in the holotype (Text-fig. 12). This specimen is the only one in which the sicula is complete, and shows the virgula tapering distally.

Fourth and later thecae.—When th 2^1 is in an early stage of development, the aboral list of th 2^2 (which indicates where th 2^2 branches from the "common canal") is in process of formation (Text-figs. 7, 8). The most proximal part of the obverse ventral list of th 2^2 is also present at this stage (Pl. 84, fig. 3). The completion of the aboral list, and the growth of the obverse ventral list, is shown in Text-figures 9, 10 (cf. Pl. 84,

fig. 4). In MCZ 522c the obverse ventral list of th 2^2 appears to have been torn out, leaving a hole in the sicula (Text-fig. 11). This same specimen shows an early-formed part of the reverse parietal list of th 2^2, and a thickening of the wall of th 1^2 and a projection where the reverse ventral list will grow (respectively "e" and "v" in Text-fig. 10). In the holotype (Text-figs. 12, 13) th 2^2 is complete.

A list tentatively identified as the aboral of th 3^1 in the holotype (upper "ab" in Text-fig. 12a) is complete at an earlier stage (Text-figs. 9, 10), and first appears still earlier (Text-fig. 8). In the original of Text-fig. 10 a list arises at the base of the obverse parietal list of th 2^1 and runs around to the antivirgella side of the sicula. It has counterpart in the holotype (Text-fig. 12), originating in a slightly different place, but where it belongs is uncertain.

Discussion.—Much of the discussion of the structure and development of *Orthoretiolites* (Whittington, 1954, pp. 619–621) might be rephrased and applied to *Pipiograptus*. To avoid such repetition I have taken the earlier discussion as a basis for the following remarks.

The time of appearance of the virgella, and mode of growth of lists of the clathria, is the same in the two genera. The specimens of the early growth stages show that the position and thickness of the various lists is not exactly the same in all individuals, and that the spines are variable in form and position. The development of *Pipiograptus* is like that of *Orthoretiolites*—the foramen of th 1^2 is large, ovate, one wall lying against the sicula, the flange grows like an awning across this foramen and the reverse wall of the sicula, and the earliest-formed part of th 2^1 branches from the flange. In neither genus does periderm grow up from the margin of the sicula to meet the advancing edge of the flange. On the basis of this development, and of the lists interpreted as aboral, the thecal diagram has been drawn (Text-fig. 14), and it is like that of *Orthoretiolites* (Whittington, 1954, Text-fig. 3) as well as those of *Diplograptus leptotheca* and *Orthograptus apiculatus* (Bulman, 1947, p. vii, Text-fig. C). In the course of the growth of the rhabdosome, each successive theca is complete while the succeeding theca is in a very early stage. The growth of the zooids, however, is evidently well ahead of that of the thecae which will contain them (cf. Bulman, 1947, p. viii) e.g., when the second theca is complete the initial portions of both third and fourth are growing (Text-figs. 7, 8), or, when the third theca is complete the initial portions of the fourth and fifth are forming (Text-fig. 10).

? Family RETIOLITIDAE Lapworth, 1873
Genus PHORMOGRAPTUS Whittington, n. gen.

Type species.—*Phormograptus sooneri* Whittington, n. gen., n. sp.

Diagnosis.—Rhabdosome scandent, biserial, straight stipes, cross-section subelliptical; sicula and proximal portion of initial bud only with continuous periderm, remainder a reticula of thin threads supported by a clathria of thicker lists; clathria includes virgella spine, apertural spines of sicula, virgula as a central strand, the median ventral lists of the thecae, and crossbars; reticula a network attached to the distal tips of the clathria (including virgella and apertural spines of sicula). Thecal apertures introverted. Development of diplograptid type.

Discussion.—*Phormograptus* has many features in common with *Archiretiolites* Eisenack, 1935, differing principally in the different direction of growth of th 1^2, the introversion of the thecal apertures, the central position of the sicula in the early-formed part of the rhabdosome, and the form of the reticula, which extends across the tips of the virgella and apertural spines of the sicula. These differences are shown by a comparison of the thecal diagrams (Text-fig. 19 and Eisenack, 1935, p. 81, text-fig. 1) and the proximal portions of the rhabdosome (Text-fig. 18 and Eisenack, 1935, Pl. 5, fig. 8).

The early growth stages of the two genera present a considerable likeness, at least superficially (compare Text-fig. 15 with Eisenack, 1935, Pl. 5, fig. 4), and it seems reasonable to regard the list which curves out from the proximal portion of the virgella spine in *Phormograptus* (v in Text-fig. 15) as corresponding to the "virgellabogen" of *Archiretiolites*, i.e. as a median ventral list of th 1^1. The list which grows down from the

outer wall of the initial bud and forms a loop attached to the wall of the sicula on the reverse side (f in Text-fig. 15), may be regarded as approximately outlining the foramen of th 1^2. This theca would then grow across the reverse wall of the sicula and out along the median ventral list (v in Text-figs. 15, 17, 18), as indicated in the thecal diagram.

The reticula at this stage (Text-figs. 17, 18) is mainly below the ventral walls of th 1^1 and th 1^2, and extends across the sicular aperture. The beginnings of its growth are shown by the original of Text-fig. 15, i.e. the threads growing from the tips of the virgella and apertural spines, and that (rl) growing out from the loop defining the foramen of th 1^2. This reverse lateral thread (rl in Pl. 83, fig. 4) is considerably longer and has divided in MCZ 524e, and an obverse lateral thread (ol in Pl. 83, fig. 4) is also present in this specimen, which originates from the margin of the initial bud on the obverse side and distally divides. It seems evident that the thecal individuals 1^1 and 1^2 have a part in the formation of the reticula, but the sicular individual may also have a part, as suggested by the growth of threads from the virgella and apertural spines, and the position of the reticula below the ventral walls of th 1^1 and th 1^2. The development of the ancora stage in later retiolotids (Eisenack, 1951), also a growth from the proximal tip of the rhabdosome, may in some way be analogous.

Alternative to the above interpretation would be to suggest that th 1^1 grows down past the list "v" before turning outward and upward, but this means that it would at first grow down, and later turn laterally slightly away from, the virgella. Such a course would be unusual, and the further course of th 1^1 in such a position (or of a more downward growing th 1^2) is obscure in the original of Text-figs. 17, 18.

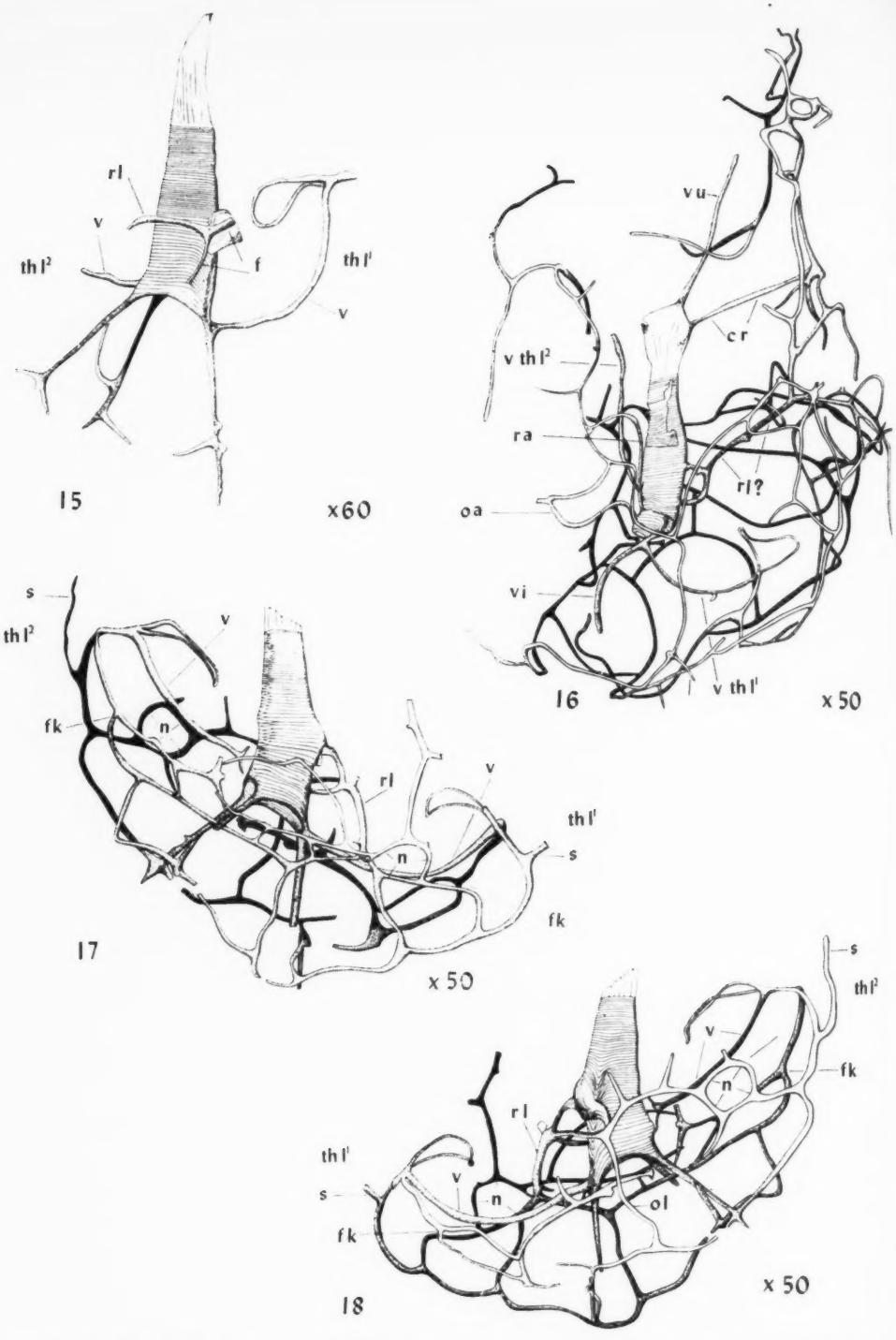
PHORMOGRAPTUS SOONERI Whittington, n. gen., n. sp.

Pl. 83, figs. 4, 5; Text-figs. 15–19

Material.—Ten specimens, MCZ 524a–j, from the lower Viola limestone of Oklahoma, and MCZ 523 (Text-figs. 17, 18) which is selected as holotype.

Description.—Dimensions in millimetres of earliest stage of development known (Text-fig. 15): length sicula 0.72, length metasicula 0.44, length virgella spine 0.5, width sicular aperture 0.2. Sicula is of normal diplograptid type, with a long, stout virgella spine and a pair of shorter apertural spines, a shallow notch in the margin between these spines. Initial bud emerges at about half the length of the metasicula from a foramen lying against the virgella on the reverse side. Only the most proximal portion of the initial bud with continuous periderm in the form of a hood, growth lines as shown. The "hood" grows down over the virgella, so that the lateral margins lie against the sicular wall on either side of the virgella. From the base of the virgella spine a stout list is directed in a curve outward and upward, and terminates in an inwardly directed loop and a blunt, outwardly directed spine. The list appears to be the main ventral list or clathria of th 1^1. From about the centre of the outer wall of the "hood" (initial bud) a list arises and is directed laterally and slightly downward. After a short distance it bifurcates, and one branch is directed downward and inward to become attached to the sicular wall a short distance inside the margin (f in Text-fig. 15). The other branch (rl in Text-fig. 15) is directed laterally. A stout list, horizontally directed, arises from the thickened margin of the sicula between the apertural spines. On the distal ends of the latter, and the virgella spine, lateral threads are in the process of formation and are brown and translucent, not black and opaque like the lists and spines. A second specimen (MCZ 524j, not illustrated) has the main list of th 1^1 broken, but that of th 1^2 is complete with terminal loop and spine. The lateral threads on the distal ends of the virgella spine and apertural spines are longer, and black and opaque, suggesting that this specimen represents a slightly later stage of development.

The original of Pl. 83, fig. 4, is peculiar in certain respects but apparently shows some further stages in development. Dimensions in millimetres: length sicula 0.64, length metasicula 0.44, width metasicula at aperture 0.14, length virgula c.0.56, length virgella spine 0.60. The growth lines of the metasicula are normal until a dark line about level with the distal margin of the



FIGS. *15–18*—*Phormograptus sooneri* Whittington, n. gen., n. sp. *15*, Early growth stage, clathria of the 1^1 complete, initial portion of clathria of th 1^2, reverse view. MCZ 542a. *16*, Proximal part of rhabdosome, clathria and reticula much distorted and broken, reverse=scalariform view. MCZ 524b. *17*, *18*, Holotype, MCZ 523, reverse and obverse views, clathria and reticula of th 1^1 and th 1^2 complete. a=apertural spine of sicula; cr=crossbar; f=list outlining foramen of th 1; fk=fork in threads of reticula; l=lateral thread of reticula; n=ring formed by threads of reticula; s=spine (actually a growing thread of the reticula); v=ventral list of theca; vi=virgella spine; vu=virgula; r and o used as prefixes denoting reverse or obverse side of rhabdosome.

initial bud is reached. Beyond this point the short portion of the metasicula is slightly constricted, such growth lines as can be seen are irregular, and there is only the reverse apertural spine. The virgella spine is of normal length, and from the base the ventral

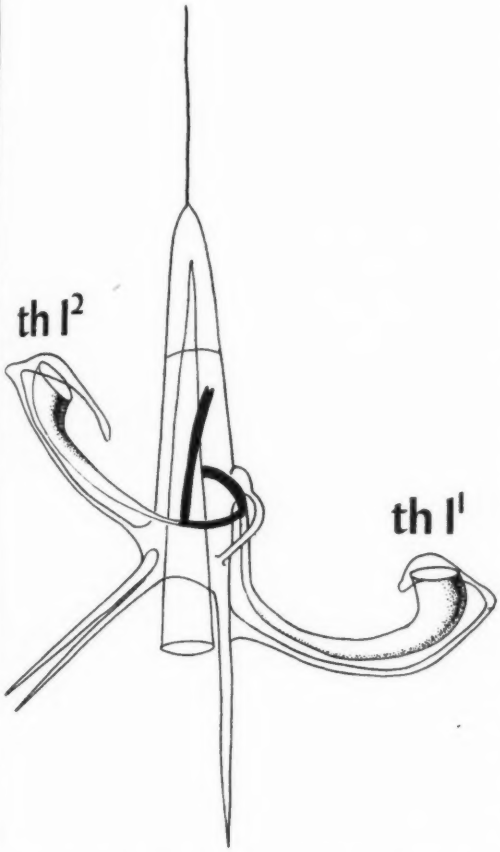


FIG. *19—Phormograptus sooneri* Whittington, n. gen., n. sp. Thecal diagram, showing approximate points of origin and directions of growth of first two thecae. "Common canal" in solid black.

list of th 1¹ curves upward and outward, but there is no loop or spine at the distal tip. The hood of the initial bud is developed as in the previously described specimens, and from the reverse wall a stout list arises, and one branch from this list curves downward and inward and is attached to the sicular wall near the margin on the reverse side. The other branch (rl in Pl. 83, fig. 4) curves upward, bifurcates, and each of these branches bifurcates. These secondary branches lie well out from the sicula on the reverse side. A second thread arises from the margin of the initial bud on the obverse side (ol in Pl. 83, fig. 4), is directed laterally, and bifurcates distally. Comparison of Pl. 83, fig. 4 with Text-fig. 15 shows that the metasicula of the former specimen is relatively shorter, the margin much nearer the level of the initial bud. This shortness seems to be the result of malformation rather than subsequent damage, and the obverse apertural list may not have been formed. There is no sign of the list of th 1², and in this respect, as well as in the absence of the loop and spine of th 1¹, and the absence of threads arising from the tip of the virgella spine, it appears to be at an earlier stage than MCZ 524a and 524j. Yet the development of the thread from the initial bud (rl and ol in Pl. 83, fig. 4) is in advance of that of these specimens.

In the next known stage (Text-figs. 17, 18) th 1¹ and th 1² appear to be complete. Dimensions of this specimen in millimetres; length metasicula 0.48, width sicular aperture 0.18; length virgella spine 0.4; transverse width of rhabdosome 1.38. The initial bud is flattened and damaged, the margin thickened and opaque. The list arising from the margin on the reverse side and joined to the sicular wall (foramen of th 1²) is clearly shown. The lateral thread on the reverse side (rl in Text-fig. 17) arises from the list defining the margin of the foramen and is now connected to additional threads of the reticula. The lateral thread on the obverse side (ol in Text-fig. 18) arises at the same point as in MCZ 524e (Pl. 83, fig. 4), and is now connected to additional threads in the reticula as well as by a short thread to the base of the reverse lateral thread. The ventral list or clathria of th 1² is complete (v in Text-figs. 17, 18, and in this specimen detached from the sicula), and there is an inward-facing loop at the extremity. From the tip of the ventral list of th 1¹ two threads curve downward and inward. That farthest out on the reverse side is joined to the tips of the secondary branches of thread rl in Text-fig. 17, as well as to the tip of the virgella spine and the reverse apertural spine. That closest to the ventral list bifurcates (fk in Text-fig. 17), rejoins, and is extended

to end beside the sicula on the obverse side. Two threads also descend from the tip of the ventral list of th 1^2, and follow courses on the obverse side that could be described in almost identical terms (compare Text-figs. 17 and 18); in other words the clathria and reticula of th 1^1 and th 1^2 are constructed in almost exactly the same way. This similarity extends to the presence of a ring (n in Text-figs. 17, 18) in the reticula on the reverse side of th 1^1 (and obverse side of th 1^2) and of upward branches from it and adjacent threads which seem to represent the upward-growing edge of the reticula.

Four other specimens seem to represent this species and suggest the general form of the rhabdosome at a later stage, but not the position of the apertures of the third and later thecae. All are incomplete, and two badly distorted. One of these (Text-fig. 16) shows the ventral lists of th 1^1 and th 1^2, with a loop at the termination of the former, and appears to retain part of the rhabdosome of the first stipe. From the list defining the foramen of th 1^2 a stout thread is directed outwards, apparently the reverse lateral thread (rl ? in Text-fig. 16). A laterally-directed list or crossbar (cr in Text-fig. 16) arises from the reverse side of the prosicula, and is connected to the reticula. A similar list may have been present on the opposite side, and is preserved in a specimen not illustrated here. Thus the lateral walls of the reticula were supported by the lateral threads and crossbars in the midline, and at the ventral edges by connections to the thecal lists. Another specimen (Pl. 83, fig. 5) has the sicula, virgella spine and ventral list of th 1^1 preserved and the symmetrical position of the lateral walls of the reticula with respect to them is revealed in this subscalariform view. However, this specimen, and comparisons between it and others, reveals that the arrangement of the threads in one wall of the reticula is not a mirror image of the opposite wall, and that the arrangement varies in different individuals. An isolated portion of the lateral reticula includes the termination of a thecal list and the apertural list, and shows that what appears to be an apertural spine at an earlier stage (s in Text-figs. 17, 18) is really a growing thread of the reticula. All the specimens show that if the loop at the end of the thecal list indicates the position of the introverted aperture, then the reticula projects beyond the aperture, somewhat in the manner in which it surrounds the sicular aperture.

CHITINOZOA Eisenack, 1931

Genus RHABDOCHITINA Eisenack, 1931

RHABDOCHITINA ? cf. R. MINNESOTENSIS Stauffer, 1933

Pl. 83, figs. 3, 6

Material.—MCZ 1021, 20 specimens, lower Viola limestone, Middle Mohawkian.

Description.—Original of Pl. 83, fig. 3 of length 1.06 mm., width 0.1 mm. Pl. 1, fig. 6, length 1.02 mm., width 0.1 mm.; other specimens of similar size. The tubular sac is open and slightly flared at one end (upper in Pl. 83, figs. 3, 6), then constricted for a short distance, the remaining portion expanding slightly toward the opposite end, which is bluntly rounded and closed. In the centre of the closed end is a small raised area. In reflected light the chitinous (?) body appears black and shiny. Some specimens are flattened, but others are partially inflated, the walls wrinkled and pitted. In transmitted light only the portion near the open end is brown and translucent, the remainder being opaque. Infra-red light penetrates the walls (Pl. 83, figs. 3, 6) showing that they are thinner near the open end, but revealing no other structure. The wrinkles in the walls increase the thickness to be penetrated and so appear as irregular longitudinal darker bands. The constricted region appears darkest partly because of stronger wrinkling of the walls, but some sediment may also be trapped here.

Discussion.—A chitinous sac like that described above was obtained by Stauffer (1933, p. 1209, Pl. 60, fig. 39) from the Decorah shale of Minnesota, and is of about the same age. Cooper (1942) has made brief reference to chitinozoans from the Paleozoic of the Mississippi Valley. Eisenack (1931, pp. 90–91, text-figs. 3–5, Pl. 3, figs. 16–18) first described *Rhabdochitina* from erratic boulders of Baltic Ordovician and Silurian rocks, and subsequently Ordovician and Silurian species have been described from Bohemia, Germany, and France (cf. Deflandre, 1952).

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JOURNAL OF PALEONTOLOGY, VOL. 29, NO. 5, PP. 852–856, PLS. 85–86, 2 TEXT-FIGS., SEPTEMBER 1955

A CRUSTACEAN FROM THE TESNUS FORMATION (PENNSYLVANIAN) OF TEXAS

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ABSTRACT—A new crustacean, *Tesnusocaris goldichi*, n.gen., n.sp., is described from the Tesnus formation (Pennsylvanian) of the Marathon region of western Texas. Its relationships are obscure. Although the first two pair of cephalic appendages are strangely modified and the presence of a fourth and fifth pair are in question, the presence of a third pair modified as mandibles characterize it as a crustacean.

INTRODUCTION

ARTHROPODS with exoskeletons not impregnated with calcium carbonate, i.e., eurypterids, xiphosurans and most crustacea, have left a meager and sporadic fossil record. When preserved, chitinous skeletal parts, or their impressions, are nearly always found in lithotopes representing unusual environmental conditions. Because of selective preservation the fossil record is far from complete. The incompleteness of the fossil record has not been given proper emphasis in most paleoecological and phylogenetic discussions. It is to be expected that divergent morphological types with no intermediate fossils to give proof of phylogenetic relationships should occasionally be discovered. Such is the perplexing fossil herein described from the Tesnus formation of western Texas.

PRESERVATION AND STRATIGRAPHIC OCCURRENCE

The fossil is preserved in a fine-textured calcareous claystone concretion about five inches in diameter and one and a half inches thick. The nodule is extremely dense, and being homogeneous, it fractures conchoidally. The surface of the nodule has weathered slightly and is light gray with limonite stains. The unweathered part is dark gray. Fortunately, when the nodule broke it fractured along the plane in which the fossil lay. Each half of the nodule bears a surface imprint of the compressed tegumentary skeleton. Dorsal and ventral features are squeezed into the same plane. Minute details, even bristles, are preserved. Only small carbonized patches of the compression of the original chitinous exoskeleton remain. Except for the posterior part of the fossil, which was broken off before the nodule was discovered, the details of the morphology of most of the exoskeleton could readily be determined.

Dr. S. S. Goldich, of the University of Minnesota, collected the specimen in 1939 in Brewster County, Texas. Many similar nodules were broken after the specimen was discovered but no other fossils were found. In reply to an inquiry concerning the stratigraphic occurrence, Dr. Goldich wrote (Personal communication, January 28, 1952):

> The fossil was loose on the ground, the two halves a few inches apart; so that I feel it could not have moved far. Similar flat calcareous concretions occur in the fissile bluish-gray shale at the locality. The shale bed is about 200 feet thick and occurs between beds of sandstone, probably near the base of the sandstone shale sequence that makes up the greater part of the Tesnus formation. Beneath is a thick section, chiefly shale, that makes up the lower part of the formation.

The only other fossils reported (King, 1937, p. 61) from the Tesnus formation are fragments of plants, a few Foraminifera and questionable sponge spicules. It is generally agreed that the upper sandstone-shale member of the Tesnus formation is Pennsylvanian in age. The age of the lower shale member is problematical, but is commonly dated as Upper Mississippian (Weller, 1948, p. 143) Apparently the crustacean was collected from near the base of the strata regarded as Pennsylvanian.

Class CRUSTACEA Lamarck, 1815
Subclass BRANCHIOPODA Latreille, 1817[1]
Incertae sedis
TESNUSOCARIS GOLDICHI Brooks,
n. gen., n. sp.
Pls. 85–86; Text-figs. 1–2

To avoid prejudicing the interpretation words implying function of part or relationship to recognized systematic categories have not been used. This specimen is unlike any known arthropod and therefore new generic and specific names are proposed.

The generic name, *Tesnusocaris*, is proposed for those Crustacea having the general organization of the type species, *T. goldichi*. Presumably differences in proportions, ornamentation or other minor details from that of the genotype will be a valid basis for establishing other species of *Tesnusocaris*. The generic name is derived from the formation in which the specimen was found and no relation to the coleopterous genus, *Tesnus*, is implied. The description of the specimen is offered as a tentative specific analysis. The trivial name is derived from that of its discoverer, Dr. S. S. Goldich.

A thin unornamented, chitinous exoskeleton originally encased the body and jointed appendages. The body consists of a fused cephalic tagma and a postcephalic tagma composed of many undifferentiated segments. The total length of the fossil is 77 mm., but the posterior extremity has been broken off and lost. Poor preservation of the last 15 mm. of the posterior portion of the specimen makes it impossible to distinguish the individual segments.

Dorsally and laterally, the cephalon is covered by a chitinous shield with free lateral and posterior margins. The shield is bluntly rounded anteriorly; 3.5 mm. and 13 mm. caudad of the anterior margin it is respectively 13 mm. and 19 mm. wide. Part of this width is due to spreading of the carapace during compression. The total length of the dorsal cephalic shield is 25 mm. About 1.5 mm. of the dorsal shield projects posteriorly over the first postcephalic segment.

Prominent sessile eyes are situated on the dorsal shield near its anterior margin. Each eye consists of approximately 800 small facets which compose a large elliptical compound eye, 2 mm. by 4 mm. The shortest axis of the eyes is oriented parallel to the sagittal plane of the fossil.

Five pairs of appendages were detected on the cephalon. The first pair are short and articulate with the cephalon on the ventral side near the axial line 6 mm. from the anterior edge. These appendages consist of a small proximal joint and a blade-shaped distal joint which bears setae on its posterior edge; the setae lengthen to form a tuft at the end. The total length of each appendage of this pair is 5.5 mm. The second pair of appendages originate about one-third of the distance back on the cephalon. These appendages are 53 mm. long, uniramous and antenniform. The basal joint is relatively large and massive and bears a setiferous lobe which projects nearly to the midventral line. The second joint is shorter and less massive. The remaining twelve joints are slender and taper gradually. Articulation between the joints of the antenniform portion of this appendage are of the fulcrum type, and it seems all were oriented so as to permit movement in only one plane. As preserved, the second cephalic appendages project laterally and posteriorly at an angle of 65 degrees to the axis of the fossil. Arising between the second pair of appendages is a bell-shaped labrum 3.5 mm. long; widening posteriorly to the same dimension. The labrum projects posteriorly over a tooth-bearing pair of appendages. Of this pair, only the heavily chitinized teeth were observed. Directly behind the third pair of cephalic appendages, two pairs of setiferous lobes were detected and these are tentatively interpreted as representing a fourth and fifth pair of cephalic appendages.

Other details of the cephalon are not decipherable except that the specimen bore

[1] AUTHOR'S NOTE. The author chose not to propose a new subclass of Crustacea on the basis of one fossil specimen. Subsequent to submitting this paper for publication, H. L. Saunders, 1955, Proc. Nat. Acad. Sci., v. 41, p. 61–66, described a new, primitive, Recent crustacean with characteristics of the Branchiopoda, Copepoda and Malacostraca. On the basis of his study of *Hutchinsoniella macracantha* the Subclass Cephalocarida was established. Until evidence to the contrary is discovered, *Tesnusocaris* should be assigned to the Subclass Cephalocarida on the basis of the unspecialized nature of the postcephalic tagma and the presence of jointed appendages.

a distinct impression of an expanded, segmented stomach. At the sides of the stomach, traces of a coiled tubular organ were observed.

Because of the significance of the features of the cephalon, an enlarged photograph (6×), Pl. 86, is presented with the parts labelled. The setae on the first pair of appendages and the setiferous lobes which are interpreted as the fourth and fifth cephalic appendages are barely discernable.

The postcephalic tagma consists of many similar segments which seemingly differ only in that they decrease in size posteriorly. Preservation of the dorsal tergites of the segments is poor and their outlines were only questionably recognized on the second, third, fourth and fifth postcephalic seg-

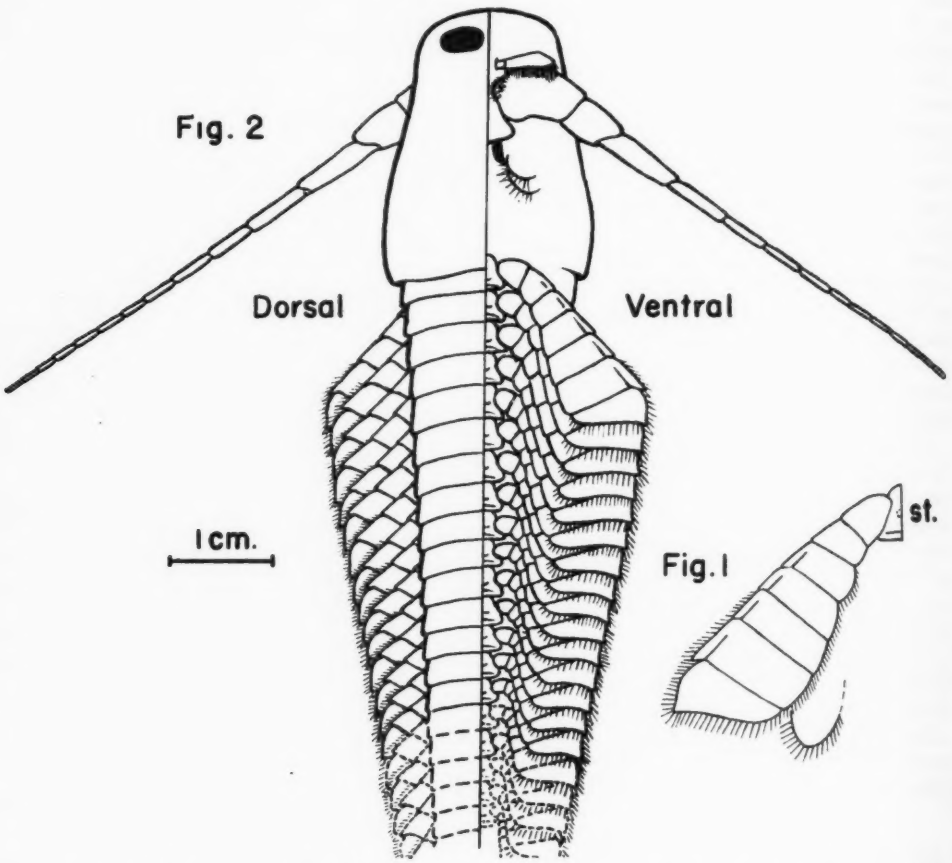
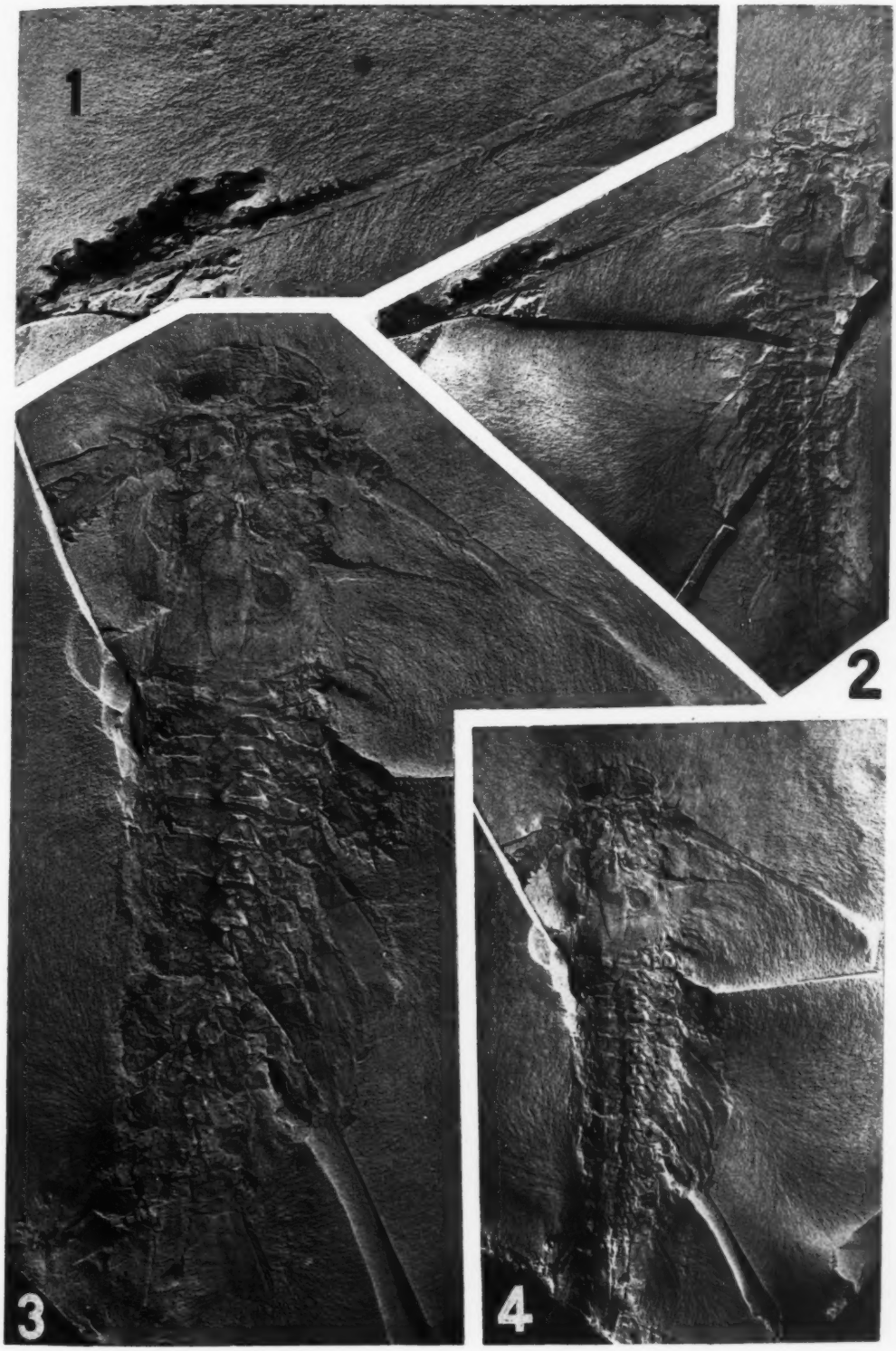


FIG. *1*—Postcephalic appendage with seven-jointed branch (exopodite?) and a membranous endopodite (?) which articulate with a sternite (*st.*), ×3.
FIG. *2*—Restoration of *Tesnusocaris goldichi* with the questionable endopodites of the postcephalic appendages obmitted, ×1.5. The posterior portion is unknown.

EXPLANATION OF PLATE 85

FIGS. *1–4*—*Tesnusocaris goldichi* Brooks, n. gen., n. sp. 1–2, Detail of left second cephalic appendage. ×2, and entire specimen, ×1; USNM 124173B. *3–4*, Counterpart, USNM 124173A, ×2 and ×1.



Brooks, Crustacean from Pennsylvanian of Texas

Brooks, Crustacean from Pennsylvanian of Texas

ments. From 23.5 mm. to 62.5 mm. back from the anterior end of the specimen, 15 heavily chitinized vertebra-like sternites were counted. Beyond 62.5 mm. to the end of the specimen, a distance of 14.5 mm., traces of appendages were recognized and testify to the original presence of additional segments.

A pair of appendages articulate with each sternite. The postcephalic appendages consist of a heavily chitinized, spatulate, seven jointed branch and possibly a lobe-like inner branch. Only a vague trace of membranous lobe was observed on the right appendage of the thirteenth pair. The biramous postcephalic appendage, as interpreted, is shown in Text-fig. 1. (The relationship of the branches is in contrast to that of the recent crustacean biramous appendage in which the outer branch is the most membranous.) The appendages of the third postcephalic segment are 19 mm. long and those of the thirteenth are 14 mm. Except for the decrease in size posteriorly, all of the postcephalic appendages were apparently identical.

Holotype.—United States National Museum, number 124173 A and B.

Horizon.—Tesnus formation.

Locality.—West of Rough Creek, 4,300 ft. S 51° E of Hill 4334 in the northwestern corner of the Dove Mountain quadrangle, Brewster County, Texas.

Systematic position.—The phylogenetic relationships of *Tesnusocaris goldichi* are obscure. Because of the presence of mandibles, it cannot be related to the crustacean-like trilobitomorphs (Størmer, 1944, p. 80–107) described by Walcott (1912) from the Burgess shale (Middle Cambrian) or to those described by Gürich (1931) and Broili (1932) from the Hunsrückschiefer (Devonian) nor can it be regarded as a chelicerate.

Though no known crustacean, Recent or extinct, has the body organization of this creature, it best can be regarded as a representative of a divergent type of Paleozoic crustacean. The Class Crustacea, as emended by Størmer (1944, p. 140–145), consists of arthropods which are characterized by having five pairs of cephalic appendages, or their rudiments, of which the third pair is always modified as mandibles. Otherwise, Crustacea vary greatly in the postcephalic segmentation of the body and in the specialization of their appendages. Until more is known about *Tesnusocaris*, it must be classified as a crustacean on the basis of the apparent homology of the cephalic appendages.

Five subclasses of Crustacea are presently recognized: Branchiopoda, Ostracoda, Copepoda, Cirripedia and Malacostraca. *Tesnusocaris goldichi* has the sessile compound eyes, carapace (dorsal cephalic shield) and large number of postcephalic segments of the notostracan branchiopods but lacks the diagnostic phyllopodous appendages. Of the other subclasses, only the copepods merit comparison but they lack the large number of undifferentiated postcephalic somites, a carapace and sessile compound eyes. Except for a questionable Triassic copepod described by Handlirsch (1914), no fossil copepods are known. Branchiopods have a known stratigraphic range from Cambrian to Recent.

The jointed, chitinized swimming branches of the postcephalic appendages of *T. goldichi* may have evolved from the outer lobe, expodite, of a phyllopodous appendage whereas the inner lobe remained a primitive membranous phyllopodous endopodite. If this interpretation is correct, this divergent crustacean should be classed with the primitive variable Crustacea of the Subclass Branchiopoda and no new subclass proposed. The species represents a new order and family. However, because only a single specimen is known and some of the charac-

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EXPLANATION OF PLATE 86

Tesnusocaris goldichi Brooks, n. gen., n. sp., USNM 124173A, enlargement of cephalon, ×6, not coated with ammonium chloride. Abbreviations: c.e. = compound eye, c.a. = cephalic appendage (3rd c. a. = mandible, 4th and 5th c.a. are questionable), l. = labrum, st. = stomach, and c.s. = coiled structure, possibly a digestive diverticulum.

teristics are uncertain or unknown, no higher taxonomic categories are now proposed.

Restoration.—A restoration of *Tesnusocaris goldichi* based on the unique specimen studied is presented in Text-fig. 2. Morphological details of the exoskeleton about which more should be known for a better understanding of the fossil are: the details of the third, fourth and fifth cephalic appendages, the segment upon which the gonopores are situated, the number of postcephalic segments and the form of the terminal segment. The supposed inner branches of the postcephalic appendages have been omitted in the restoration.

ACKNOWLEDGMENTS

Dr. F. M. Carpenter and Dr. H. B. Whittington of Harvard University and Dr. K. E. Caster of the University of Cincinnati read a preliminary copy of this paper and contributed many helpful suggestions. Special recognition is due to Dr. S. S. Goldich of the University of Minnesota, the collector. He provided the stratigraphic information presented and kindly checked the paper for accuracy.

MANUSCRIPT RECEIVED DECEMBER 10, 1954

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JOURNAL OF PALEONTOLOGY, VOL. 29, NO. 5, PP. 857–867, 4 TEXT-FIGS., SEPTEMBER 1955

TRAILS AND TENTACULAR IMPRESSIONS OF ORTHOCONIC CEPHALOPODS

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ABSTRACT—Trails and impressions on the surfaces of strata in the Corryville beds of Cincinnati are attributed to orthoconic cephalopods of the genus *Orthonybyoceras*, shells of which are extremely abundant there. Simple linear impressions with shells at the end indicate that the animal came to the bottom, moved forward, and died. Short linear impressions result where the animal came to rest, moved forward, and rose again. One grouping of such impressions suggests that the animals gathered to feed at a mass of organic debris concentrated by waves and currents. Indications are that the animals swam forward rather than backward, and that accidental breakage of the shell commonly occurred in life.

Horseshoe-shaped groups of crescentic or vermicular impressions, extremely abundant in one layer, are regarded as made by cephalopods clinging to the substratum with their tentacles to resist movement by wave action. If so, the animals had relatively long and relatively few arms, probably ten. In arm number and habits these cephalopods appear to be closer to living squids than to *Nautilus*.

INTRODUCTION

NAUTILOIDS are significant and, indeed, sometimes dominant elements in Paleozoic faunas. It is recognized that they were, on the whole, motile animals, some dominantly swimmers, some dominantly benthonic (Teichert, 1933, Kobayashi, 1936, Flower, 1942, also in press: Paleoecology of the Paleozoic Nautiloidea: National Research Council Symposium on Paleoecology, submitted 1952.) It is to be expected that such animals must have contributed to the tracks, trails and other impressions, the "problematica," which abound on the surfaces of many Paleozoic strata. Such impressions have been attributed to almost all other types of fossils which were motile to any degree. Attention has been given to markings made where less motile forms, as the brachiopods and Bryozoa, have been moved over surfaces by waves and currents. It is the more remarkable that there is almost no mention in the literature of markings for which the nautiloid cephalopods may have been responsible. It is worth considering whether the nautiloids have been overlooked in this connection, or whether they have been rejected as possible agents because the markings failed to conform with what was expected on the basis of purely theoretical considerations.

Billings (1866) described a trail which he named *Saerichnites*, and which he suggested might have been made by a cephalopod. S. A. Miller (1880) described as *Petalichnus*, *Tetraichnus* and *Trachomatichnus* other trails which he suggested might have been made by cephalopods. These four types of markings seem to be the only impressions in the Paleozoic of North America which have been attributed to the cephalopods, and these attributions have been made only in the most tentative terms. I have not searched the European literature as closely, but it appears to be completely free from any mention of impressions or trails which might have been made by nautiloid cephalopods. Yet the nautiloids, as animals that must have moved along the sea floor, must have left some impressions when they did so. It is not too much to hope that they left impressions also of their soft parts. Anyone who has tried to eat squid and has given up trying to chew the tentacles, will realize that to call them "soft parts" is, if not a gross exaggeration, at least a euphemism.

The markings described below were first observed in the spring of 1940 on surfaces of the Corryville strata in Stone Lick Creek, roughly 1.5 miles southwest of Newtonsville, Ohio. At that time both Dr. K. E. Caster and I recognized that they were probably made by the orthoconic cephalopods which are so abundant in the same beds. Only a few specimens were collected, and facilities for taking photographs in the field were lack-

ing. Rock surfaces in the streams of this region change rapidly. The thin limestones separated by thin layers of shale, are readily broken and removed by every period of appreciably high water. Change is further accelerated at this locality by man. The thin limestones are extensively broken up and removed for fill and other purposes. Other duties intervened, and further visits to this locality yielded no equally good specimens, or exposures suitable for photography. When on a return trip to Cincinnati from New Mexico, the locality failed once more to yield good material for photography, it seemed best to publish the results of my earlier observations, even though they are not as well illustrated as might be wished.

In the meantime, various matters caused these trails to assume greater importance. The preparation of the chapter on Paleozoic Nautiloidea for the Treatise of Paleoecology, soon to appear, reminded me again that almost nothing was known of trails and impressions made by Paleozoic nautiloids. Likewise, there was much uncertainty concerning their habits and mode of life, to the understanding of which these markings contributed. The need was again emphasized by requests for advice on how to deal with nautiloids in reconstructions of Paleozoic life. Such requests ranged from extensive correspondence with Mr. I. G. Reimann concerning the cephalopods in the Ordovician group made for the Royal Ontario Museum at Toronto, to a telephone call one Saturday afternoon from a gentleman on the staff of Life Magazine. He wanted immediate information on color patterns of shells, appearance of the head, number of tentacles, and, so help me, whether the eyes were blue. I will forestall further discussion of this last item by stating that neither I nor, as far as I know, anyone else, has confidential information on the color of the eyes of Paleozoic nautiloids. Surprisingly, together with the evidence of the trails described below, some contributions can be made to almost all of the other questions commonly involved in the treatment of cephalopods in reconstructions of Paleozoic life. The tentacle impressions have also some interesting implications in relation to current views on phylogeny and classification of the cephalopods as a whole.

It is hoped that the present discussion will stimulate interest in further observations of the sorts of trails and markings here described. More detailed observations are much to be desired. Also, I would urge consideration of the cephalopods as the possible agents of still other and different markings. The group is a large one. Probably the habits of the animals varied as widely as did their shell forms. It is highly probable that other and different cephalopods may have produced markings quite different from those described below.

FEEDING AND RESTING TRAILS

The Cincinnatian strata commonly show long linear trails, relatively straight, shallow, rounded in cross section. The first indication that cephalopods might be responsible for such markings was found at Stone Lick Creek. There such trails were found with occasional shells of the genus *Orthonybyoceras* (=*Treptoceras*) at their ends. (Text-fig. 1A). The shell lay with the aperture, and not the apex, directed forward beyond the trail, suggesting that the animal had come to rest upon the bottom, moved forward a short distance, and died, leaving its shell at the end of the trail. I was at first inclined to reject the evidence of this specimen. It suggested that the animal both crawled and swam forward. We have generally believed that the straight nautiloids swam in the opposite direction, with the tip of the shell in front, the tentacles trailing behind. This belief, of course, is based upon the movements of the living genus *Nautilus*. It has had its perplexing points. It is hard to see how a straight cephalopod could have been an effective swimmer, or very active as a predator, if it moved primarily backward. Evidence from two sources suggests that the animal did move forward, both in swimming and possibly in crawling, and that the analogy based upon *Nautilus* may have no bearing.

A single example of a cephalopod shell, as described above, at the end of a trail, could be dismissed as accidental. However, four or five such trails were found with the cephalopod shells always in the same position at their ends. If the association were accidental, one would not expect to find the shells always oriented in the same position at the

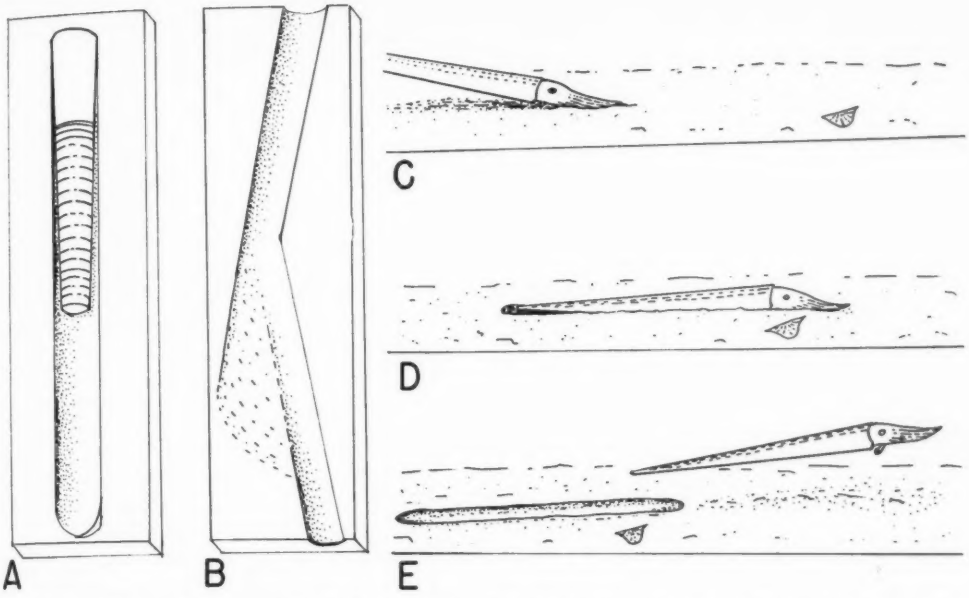

FIG. 1—Feeding and resting trails of *Orthonybyoceras* A. Linear trail with shell at the end, suggesting that the cephalopod, came to the bottom, moved forward, and died. B. Linear trail attributed to *Orthonybyoceras*, in which the animal turned, swinging around the apex of the shell and widening and blurring the impression. C–E. Interpretation of how orthoconic cephalopods could produce short linear trails. In C the animal is swimming forward, approaching the bottom, coming to rest in D, and rising and swimming away forward in E. The three diagrams are somewhat telescoped laterally, orientation is supplied by the brachiopod shell on the bottom, included as a stationary point.

end of a linear trail. Further, one would expect to find cephalopod shells, or fragments of them, in the middle of such linear depressions, and not always at their ends. It therefore seemed unlikely that a dead cephalopod shell happened to come to rest at the end of a trail made by some other organism.

Nautilus is known to move only backward when swimming by extruding water from its forward-pointing hyponome. In the absence of any previous evidence, it has been assumed quite generally that all of the Nautiloidea could swim only with the head and hyponome similarly bringing up the rear. However, Dr. J. W. Wells first called my attention to a fact which was at that time new to both of us: that living squids can swim as readily forward as backward by turning the tip of the hyponome backward. This he had observed in a marine aquarium in England, and some years later I had an opportunity to observe the same versatility in small *Loligo* in the aquarium at Wood's Hole, Massachusetts. A squid moving in this way is propelled mainly by extrusion of water from the hyponome. Motion is aided by action of the fins, but their function seems to be primarily a stabilizing one. The tentacles are held together forming a flat transverse prow, which is moved in accordance with any change of direction. Together with the fins, this prow serves as an amazingly efficient steering mechanism. The importance of the tentacles in this respect was a real revelation. If an orthoconic nautiloid also used the tentacles as a steering device, it could have been a relatively efficient swimmer, even without the fins. The concentration of cameral and siphonal deposits on the ventral side of the shell (Teichert 1933, Flower, 1939) would serve to stabilize the animal. If the animal could reverse the position of the hyponome, it could swim forward as easily as these squids. The prevalence of a good hyponomic sinus in orthoconic nautiloids and the evidence of the present trails converge to suggest that such forward motion was not only possible,

but was probably dominant. It has long been evident that some orthoconic cephalopods were capable of quite extensive swimming from their penetration into impure and, more rarely, even pure planktonic assemblages (Ruedemann, 1934).[1] For these reasons it seems legitimate to regard the trail described above as made by a cephalopod which swam forward, came to the bottom, moved forward a little, and died. If so, a still more interesting conclusion can be drawn. All shells found at the end of such trails were incomplete apically. If interpreted correctly, the shell must have been broken prior to the death of the animal. Was breakage of the shell the immediate cause of death in each case? It seems unlikely. These specimens suggest rather that accidental breakage of the shell was not an uncommon phenomenon in living orthoconic cephalopods. This is a matter quite apart from the natural and regular truncation of the shell, with cementation of the apex of the siphuncle, such as is typical of the Ascoceratida, and the remarkable "*Orthoceras*" *truncatum* Barrande. This is, as far as I am aware, the first evidence indicating that loss of the apex of the shell, though accidental, may have been a common phenomenon in orthoconic cephalopods. There has previously been no indication that the fragmentary nature of most specimens is not completely due to breakage of the shells after death. It should be noted that the shells break just apicad of the septal surfaces. This is a natural point of weakness, one at which the wall of the phragmocone is weaker than elsewhere, because the mural part of the septum (Teichert, 1933; Flower, 1939) typically terminates slightly apicad of the free part of the next adoral septum.

Assuredly, it would be a sad mistake to assume that orthoconic cephalopods were the only creatures which could produce essentially straight linear trails. Such markings can, of course, be the work of a variety of organisms. One somewhat similar trail was found with the two valves of a pelecypod in life position at the end. However, trails made by orthoconic cephalopods may be expected to show one important feature. The length of the shell will require that the trail be relatively straight. If a turn occurs, the trail will be blurred and widened, for the animal will have to swing the apex of the shell around in a new direction. Just such a phenomenon was observed in one trail, indicated by the sketch shown in Text-fig. 1B.

Far more common than the long linear trails to which attention has thus far been confined, are short straight linear impressions, shallow, rounded in cross section, and bluntly rounded at both ends. Such markings occur in extreme abundance in many horizons in the Cincinnatian section. They form what have come to be commonly known as the "turkey track layers." Text-fig. 1C–E shows how such markings can be made by orthoconic nautiloids. Text-fig. 1C shows an animal descending to the bottom, moving forward, and about to come to rest. Resting position is attained in Text-fig. 1D. While in this position the animal may move forward to varying extents, the extent determining the length of the individual impression. Swimming forward and rising (Text-fig. 1E), it would leave behind just such a linear impression as is commonly found. As far as I am aware, this is the only convincing explanation which has been offered for such markings.

If the animal held the tentacles together to form a flat prow for steering, no tentacular impressions would be made on the substratum. No tentacular impressions have been found associated with such linear trails. One might wonder whether the animal, if propelled forward by a backward-pointing hyponome, might not leave either an impression of the hyponome, or a small excavation made in the sediments eroded by water ejected from the hyponome. Any such markings which might have been made would be extremely shallow, and would in all probability be eliminated by dragging the shell over the region where they were made. Shells of orthoconic cephalopods were very light by virtue of gas in the camerae. Teichert

[1] Orthoconic cephalopods are common in the impure planktonic assemblages of the Utica, Cannajoharie and Snake Hill shales of the Ordovician. In the Silurian, they are sometimes the only organism, other than possible ostracodes, found in shales with *Monograptus*. They are significant faunal elements in Devonian black shales, notably in the Marcellus shales of the Middle Devonian, and the Genesee shales of the Upper Devonian.

(1933) has presented careful estimates indicating that even with moderate cameral deposits, which are confined to the apical part of the phragmocone, the entire animal of *Orthonybyoceras* would not be materially heavier than the volume of water which it displaced. Being light, the animal could be propelled easily by a relatively weak jet of water from the hyponome. If the bottom mud was at all consolidated, it would be affected scarcely, if at all, by the force of water from the hyponome.

One most remarkable assemblage of such impressions was found centered about an area of irregular debris (Text-fig. 2). The debris contained portions of trilobites, shells of brachiopods and much unidentifiable material. It was obviously originally a mass of organic detrital material concentrated by action of waves or currents. About this central mass, occupying a surface roughly 3 feet across, were clustered intersecting short straight linear trails. The whole pattern occupied an area 8 to 10 feet across. One could easily visualize that the cephalopods, partaking of something of both the carnivores and scavengers in their habits, had clustered here to feed, descending to the bottom, resting, feeding, then rising to swim away or returning to attack the food supply from another angle.

It is worthy of note that the short straight impressions here attributed to orthoconic cephalopods are by no means confined to the Cincinnatian. They are, in general, the sort of marking which Hall named *Fucoides graphica*, common in many parts of the Paleozoic. They are again abundant in the Ithaca shales of the Upper Devonian of central New York. Clarke (1916, pls. 20–23), has figured such markings which he sought to attribute to crystals of bottom ice, an interpretation which may account for some such markings, but which I have never found very convincing for the markings common in the Ithaca shales. There they are consistent in size with the cephalopods also present, the larger ones matching *Dolorthoceras bebryx* var. *cayuga*, others matching smaller orthoconic species, while some extremely small and slender ones are consistent in proportions with the species of *Bactrites* which could have made them.

The Cincinnati trails discussed above occur in beds in which only two genera are common: small to medium sized orthocones of the genus *Orthonybyoceras*,[2] and endoceroids belonging to *Endoceras* in the present broad sense in which this generic name is necessarily employed. As previously noted (Flower, 1946, p. 110–111), these two genera contain the dominant Corryville cephalopods, and all of the orthoconic ones. No *Michelinoceras*, and indeed, none of the Michelinoceratida have been found there, though several hundred orthocones have been collected and studied. The remaining species, brevicones and cyrtocones, are rare, so rare that they are known only from one or two specimens each. The markings described above have clearly been made by *Orthonybyoceras*. They are consistent with such shells in size. One of the trails shown in Text-fig. 2 is of such proportions that it was certainly made by an endoceroid. I have also observed an endoceroid at the end of a trail

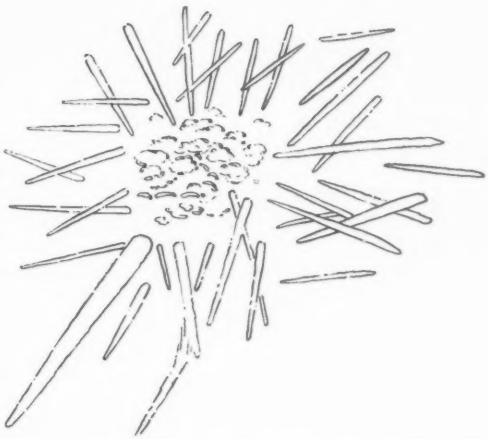

FIG. 2—Sketch of cephalopod trails centered about a concentration of organic debris, suggesting that the animals congregated here to feed.

[2] I am indebted to Dr. Teichert for pointing out to me that my genus *Treptoceras* must certainly include *Ormoceras covingtonense*, Foerste & Teichert, which Shimizu & Obata (1935) had earlier made the basis of their genus *Orthonybyoceras*. I have dealt elsewhere with the genera of annulated orthocones proposed by these authors (Flower, 1943), It became evident that their descriptions had little connection with the morphology of the species on which they were based.

not unlike that shown in Text-fig. 1A. However, the impression was short, the shell very incomplete, and it could possibly have been the impression of a dead shell from which the apical part was broken and later washed away by waves or currents.

TENTACULAR IMPRESSIONS

Curved and deviously winding markings generally regarded as the work of worms, are common throughout the Cincinnatian. One surface in the Corryville beds of Stone Lick Creek showed a remarkable series of such impressions for which this explanation proved wholly inadequate. There short curved or vermicular markings were arranged consistently in groups, each group showing a crescentic or horseshoe-shaped pattern. These markings were found only in one bedding plane, but occurred in that in such abundance that individual patterns overlapped. There could be no doubt but that the horseshoe-shaped arrangement was an essential feature of the pattern, and that each pattern was the work of an individual animal, rather than a fortuituous grouping of individual worm markings. Happily, some of the clearest of the markings were collected, and two of the best are shown in Text-fig. 3A and B.

The number of individual markings in each pattern varied, but within limits, from 6 to 13. The clearest impressions suggested that they were made by an animal with ten slender flexible appendages.

The clearest of the markings showed a pattern with a definite bilateral symmetry. Normally the individual markings were curved, and so arranged that the concave side of the curves faced the plane of symmetry. Where the individual markings were short curves, each describing less than a semicircle, the whole pattern was relatively long and horseshoe-shaped. Where the individual markings were longer, each forming a complete semicircle or more, the entire pattern was broader and shorter, and not narrowed at the posterior or open end.

What made these markings? Clearly they could not be dismissed as a chance arrangement of individual vermicular markings made by individual worm-like animals. The crescentic arrangement is too universal to be dismissed as fortuituous. Each group was obviously made by a single animal. The animal was one which either rested so lightly on the bottom as to leave no impression of its body, or else rested suspended in the water slightly above the sea floor. It was an animal which was grasping the bottom with a series of arms, evidently flexible, paired, relatively few in number, and probably arranged in five pairs. The actual number of arms could, of course, be estimated only from a study of many of these impressions. Less than the real number would be indicated if the animal did not always employ all of its arms in clinging to the bottom. Again, a higher number would be indicated, if the animal moved one or more of the arms to take a fresh hold on the substratum. The animals which made these markings must have occurred in great abundance. Unless they were completely soft bodied organisms, they should be some group of fossils abundantly represented in the Corryville beds. True, no fossils whatsoever were found in the immediate layer bearing these impressions. This, as will be seen, is to be interpreted in terms of conditions of sedimentation, and is of no immediate importance to the problem of what animal made the markings.

Holothurians, or other echinoderms are at once suggested by the estimate that the animal possessed arms in a multiple of five. True, echinoderms are known to occur in great abundance in just the sort of isolated association that is found here. But holothurians, the most likely echinoderms, are not only bottom dwellers which would be expected to leave impressions of their bodies but are often inclined to be burrowers. Burrows and deep body impressions would be expected. Further, it is doubtful whether any echinoderm would grasp the substratum in such a way as to leave such regular bilaterally symmetrical patterns.

The interpretation reached as to the cause of the markings is shown in Text-fig. 4. They are regarded as made by *Orthonybyoceras*, grasping the bottom with its tentacles. These straight cephalopods are the only fossil forms known in associated strata which fulfill the above listed requirements of the animal which must have made the markings. They are extremely abundant in the Corryville beds. The air-filled phragmo-

cone would make the animal light enough that its body and shell could be suspended in the water, while it grasped the substratum with its tentacles. Further, from all estimates, these animals were light enough so that they would be very readily moved by waves and currents. It is natural that they should have grasped the bottom with their tentacles to resist the motion of water. One could see that such action would be necessary to keep the animals from being swept along by strong currents. Currents are not a likely explanation for the present association; if they were, the markings would be expected to show some uniformity of orientation, which was completely lacking. It therefore seems likely that the animals were grasping the bottom to resist the turbulent movement of wave action. The cephalopods possessed tentacles which were clearly paired, arranged in a bilaterally symmetrical pattern, and would be expected to leave such impressions as those under discussion. That as few as five pairs are indicated is surprising but is no cause for rejecting the above explanation. Previously there has been absolutely no evidence as to the number of arms present in any Paleozoic nautiloid.

The features discussed above are shown in the two impressions illustrated in Text-fig. 3. Text-fig. 3A shows the most perfect and complete specimen observed. Its interpretation is shown in Text-fig. 4A. This group of markings is 60 mm. long and 65 mm. wide. Five crescentic markings are present on the right, only four on the left. Plainly, the left side lacks the counterpart of the lowermost impression visible on the right. Individual markings are crescentic, each less than a complete semicircle. In every case, the convex side of the curve is directed outward, away from the plane of symmetry. On the right side, the individual markings seem to have their anterior ends well defined and deeply incised. The posterior ends become shallow and disappear gradually. From this side alone, one could infer that the arms grasping the bottom curved inward and forward at their tips as suggested in Text-fig. 4C, as viewed from above, and 4G as viewed laterally.

The opposite side, however, could be interpreted differently, as shown in Text-figs. 4D and H. It shows faint markings apparently aligned with the anterior end of the stronger cresentic markings, passing obliquely toward the place where the head would be expected. The symmetrical alignment of the markings on the right and left.

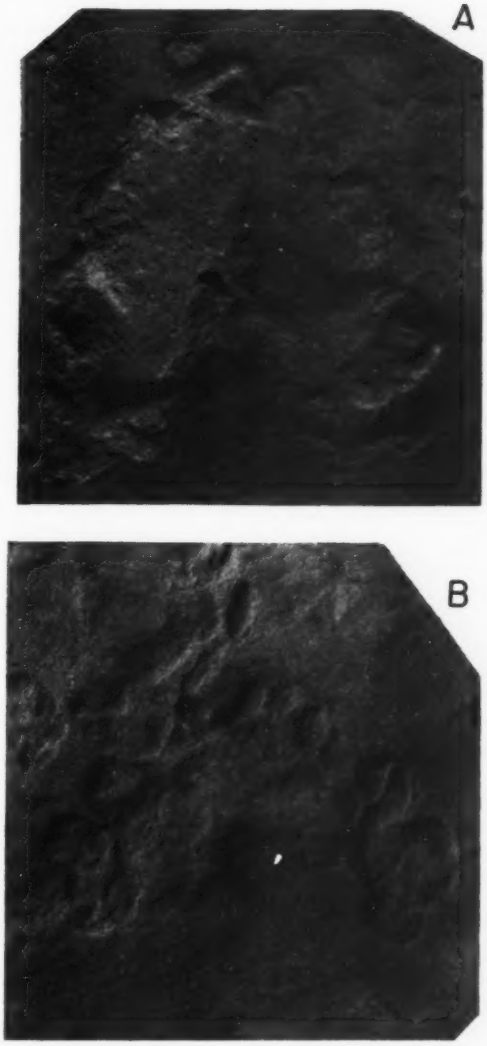

FIG. *3*—Photographs of impressions attributed to the tentacles of orthoconic cephalopods of the genus *Orthonybyoceras*. (About ×0.8). A. The most perfect impression observed, showing nine distinct markings, in an elongate horseshoe-shaped arrangement. B. A second specimen, in which the pattern is shorter and broader, and individual impressions are longer, describing somewhat more than a semicircle.

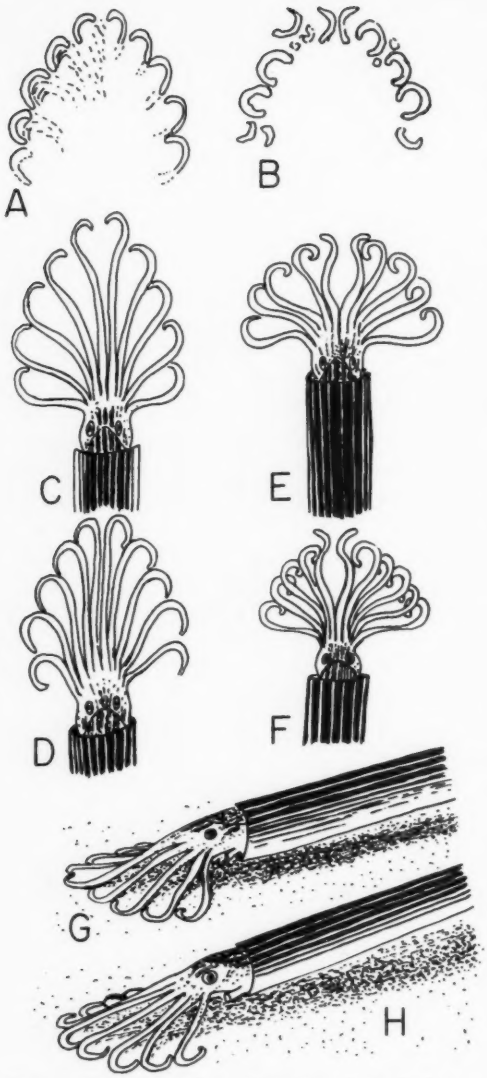

FIG. 4—Interpretation of the impressions shown in Text-fig. 3. A. Sketch of essential features of the impression shown in Text-fig. 3A. It is regarded as made by a cephalopod holding the substratum with its tentacles, either as represented in B and G, as viewed from above and from the side, or as shown in C and H. The interpretation shown in B and G is regarded as the more probable of the two. B. Sketch of impression shown in Text-fig. 3B. E and F are two possible positions of the animal, and its tentacles, by which this impression could have been made. Here more of the tentacle length is used in grasping the bottom. Consequently the free arm length is shorter, the impression is broader and shorter, and the head and shell aperture lie slightly farther forward in relation to the general pattern.

make it unlikely that the arms were curved in one direction on one side and in the opposite direction on the other. Probably the faint markings on the left which suggest that the tips of the arms were curved outward and backward, are fortuituous. An oblique linear marking slightly left of the center is probably a worm trail or tube. The faint markings are aligned with it, and may well be feeding trails of a worm. If so, they have nothing to do with the tentacular impressions. Nevertheless, as the present evidence is not sufficient to support the one interpretation to the complete exclusion of the other, it has seemed best to indicate both possible positions in the accompanying figures.

A second impression, Text-fig. 3B, shows a general pattern which is broader, shorter, lacking the narrowing at the posterior end, and the individual tentacular impressions are longer, and each describes more than a semicircle. The whole impression is 70 mm. wide and 40 mm. long. The anterior two impressions are curved outward, the others are all curved inward as in the preceding specimen. The individual impressions are not as clearly made out here as in the previous specimen; in part, this impression is complicated by other but fainter patterns of the same sort. It is not possible to make out five pairs of impressions. The markings, shown in Text-fig. 4A, could be interpreted as being made either as in 4E or F. In E it is assumed that there is a posterior-lateral pair of tentacles which made no complete impression of their tips, but which could have been responsible for some of the imperfect markings shown at the base of Text-fig. 4B. In Text-fig. 4F it is assumed that the lack of clarity of the individual markings is to be explained by their close proximity. Doubtless also, some movement of the arms is recorded. According to this interpretation, the irregular markings at the base of the specimen are to be dismissed as adventitious.

In both impressions there is a faint depression in the lower part, where one might expect the shell aperture to be. The present evidence is not sufficient to show that it is significant; it may be completely accidental.

Admittedly, there is always a certain amount of inference in attributing any trails or impressions to animals which are extinct. The element of uncertainty is relatively

small when one is dealing with forms which can be interpreted in relation to either closely related or strongly analogous living forms. It is of course greater when, as with the orthoconic nautiloids, there is nothing closely similar living today. I have approached the problem on the premise that these animals must have been responsible for some of the trails and impressions, and those discussed above are, firstly, those for which the cephalopods supply a logical explanation, and secondly, they are markings for which no other known organisms seem to supply an adequate explanation.

The conclusions to be reached from a study of the trails are in some respects surprising, but the element of surprise is present because they are not quite what most of us would have expected. Any conflict is between them and previous concepts, not previous evidence. The conclusions reached may be summarized as follows:

1. Orthoconic cephalopod shells at the end of linear trails are reasonably explained by the assumption that the animal swam, came to rest on the bottom, moved forward, and the shell remains where the animal died.

2. Short linear trails rounded at both ends, are made where the cephalopod came to rest on the bottom, moved forward, and then rose again and swam away.

3. Similar trails clustered about what was originally a collection of organic debris suggest that the cephalopods clustered there to feed.

4. Orthoconic cephalopods are potentially active swimmers. The present evidence suggests strongly that they moved forward more typically than backward. Propulsion is supplied mainly by the hyponome which, for forward swimming, must be pointed backward as in modern coleoids. Steering is effected as in modern coleoids, by the tentacles, which may have been held together to form a transverse prow, as has been observed in *Loligo*. The ventral concentration of cameral deposits in the shell would serve a stabilizing function, as do the fins in the coleoids. It has been noted elsewhere (Flower, 1939, and in press), that the apical concentration of cameral deposits was such as to permit active movement with the shell held horizontally in life. Probably the centers of buoyancy and gravity were maintained at the midlength of the animal throughout life. At the same time, the weight of the deposits would be slight enough that in most straight cephalopods the animal would not be materially heavier than the volume of water it displaced; an adaptation for an essentially nektonic existence is strongly suggested.

5. Tentacular impressions are interpreted as preserved where *Orthonybyoceras* grasped the bottom to resist the turbulent motion of the water resulting from wave action. This condition was probably exceptional. Certainly such markings are exceptional, and have thus far been found in abundance only in a single bedding plane.

6. The tentacular markings suggest that the cephalopods which made them possessed five pairs of tentacles.

7. The evidence suggests that the orthoconic shells found at the ends of trails may have lost apical parts of their shells in life. Accidental loss is involved, not a normal shedding of apical parts of the shell as in the Ascoceratida and a few other specialized forms. The present evidence suggests that such accidental loss may have been a relatively common phenomenon, a condition which the animal could survive. This is a question for the solution of which there has previously been no direct evidence.

The above discussion has indicated the degree of probability with which these conclusions are regarded. Admittedly, interpretation of these trails is hazardous. Explanations can be presented as convincing interpretations, but can never be proved absolutely. Further observation of these markings is needed, with more extensive observation and better documentation in terms of photographs in the field, and a more extensive collection of specimens. Such a study should serve as a further test for hypotheses here regarded as reasonably well established; it should supply an answer to many of the questions which cannot be answered definitely from the present observations. The present study is offered as a contribution to a subject totally neglected in the last 75 years, viz. impressions for which the orthoconic nautiloids of the Paleozoic were probably responsible.

PHYLETIC AND TAXONOMIC IMPLICATIONS

The evidence discussed above suggests that the orthoconic nautiloids responsible

for these markings were not unlike some living squids in both their habits and the organization of the soft tentacles. In the absence of any previous evidence, we have been accustomed to assume that the fossil nautiloids as a group probably had many short arms rather than relatively few long ones. This assumption was based upon the condition known in *Nautilus*, the only living representative of the cephalopods with external shells. The present evidence supports a suspicion which I had long entertained, namely that *Nautilus* might be an extremely unreliable guide in this respect, and that it is unsafe to apply generalizations based upon *Nautilus* to the whole of the Nautiloidea.

In the past, also, there has been a temptation to apply much evidence supplied by one species, or a few species, too widely in the fossil cephalopods as a whole. It is essential in matters such as those under discussion, that the evidence be considered in relation to the phylogenetic position of the species which supplies it to the Nautiloidea, and indeed, to the Cephalopoda as a whole.

The Coleodia sprang from the Michelinoceratida sometime prior to the Middle Mississippian, from which the oldest belemnoid so far known has already been recorded (Flower, 1945.) There has been no direct evidence as to the number of arms or appearance of the head of any member of the Michelinoceratida (See Flower & Kummel, 1950). That trails similar to those described from the Cincinnatian occur also in the Ithaca shales is some indication that the Michelinoceratida possessed swimming habits similar to those described above for *Orthonybyoceras*. These trails were made by members of the Pseudorthoceratidae, possibly some Michelinoceratidae, and Bactritidae. That the head was similar in organization in the ancestral Michelinoceratida and the descendant Coleoidea is a reasonable inference. However, the only case in which there is any indication of the number of arms in fossil nautiloids is the genus *Orthonybyoceras*, which is not in the Michelinoceratida, the direct ancestor of the coleoids, but in the Actinoceratida. It can be traced to the coleoids only by retracing its ancestry into the archaic Ellesmeroceratida, and thence on through the Michelinoceratida. Therefore, one must clearly select either of two possible conclusions: 1. That the number of arms was reduced once in the Actinoceratida, possibly in its immediate ancestors, possibly at the inception of the order, possibly somewhere within it, and then again somewhere in the phyletic stock included in the Michelinoceratida and Coleoidea. 2. That the primitive cephalopods actually had relatively few and relatively large arms, instead of the many short ones which we have assumed they possessed, basing our assumption on the organization of *Nautilus*. Closer inspection shows that the second possibility is perhaps more likely than the first, and much more likely than it first appears. It is now evident that *Nautilus* is the lone survivor of a phyletic line which has undergone devious changes in form and structure, in which we may expect to encounter profound modifications both in the mode of life and in the organization of the soft parts. To unite *Nautilus* with either the actinoceroids or the Michelinoceratida-Coleoidea line, its ancestry must be traced through the following steps: 1. Back through coiled cephalopods of quadrate whorl, the Centroceratida of Flower & Kummel (1950). 2. This stock is probably traceable (Flower, 1952,) to the loosely coiled Rutoceratida of the Devonian. (3) The ancestry of the Rutoceratida, as will be shown elsewhere, is now definitely established to be not in the older coiled cephalopods, as was generally believed, but in the cyrtocones and brevicones of the order Oncoceratida. (4) The Oncoceratida traces its ancestry back to the Basslerocerati da, the first exogastric cyrtocones, which must, in turn, have sprung from the archaic Ellesmeroceratida. In tracing this history forward, one encounters first, the appearance of exogastric curvature, and second, the development of coiled shells from those which were cyrtoconic and even breviconic. Both changes involve critical changes in the mode of life, and it is at these points in the evolution of a stock that profound changes in the organization of the soft parts may be expected. Certainly the arms of *Nautilus* are specialized in their differentiation into thick basal and thin distal regions.

If, in habits and organization of the arms,

both the Michelinoceratida and the distantly connected Actinoceratida were more similar to the Coleoidea than to *Nautilus* itself, we may again wonder whether the tendency to include all cephalopods with external shells in the Tetrabranchiata (in which we hope that the 2500 extinct genera share the four gills of the one living one) is not wishful thinking. A division of the Cephalopoda into three equivalent groups, the Nautiloidea, Ammonoidea and Coleoidea, is to be urged as preferable inasmuch as it rests more upon ascertained facts, and less upon supposition.

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JOURNAL OF PALEONTOLOGY, VOL. 29, NO. 5, PP. 868–870, PL. 87, 1 TEXT-FIG., SEPTEMBER 1955

A NEW DEVONIAN TEREBRATULOID BRACHIOPOD WITH PRESERVED COLOR PATTERN*

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ABSTRACT—A new genus and species of terebratuloid brachiopod, *Maclarenella maculosa*, is described from the Middle Devonian Waterways formation of western Canada. The specimens available show well-preserved color markings as radial rows of spots.

INTRODUCTION

IN EXAMINING the paleontological collections of the California Institute of Technology, the writer chanced upon two specimens of a remarkable color-marked terebratuloid brachiopod. Locality data indicated that they had been collected from the Devonian Waterways formation of western Canada. Four additional specimens of this species have been procured and studied, both externally and by means of serial sections. A new species is represented and in turn requires the erection of a new genus for its reception.

TEREBRATULOID COLOR MARKINGS

The presence of color markings in fossil terebratuloids is known from infrequent finds from the Devonian onwards. The markings are either radial bands, concentric bands, or radial rows of spots. Rows of spots characterize the Waterways species and appear similar to those of *Hamburgia morsii* Cloud. Cloud (1942, p. 22) indicated the possibility for *H. morsii* that what were apparently spots might have resulted from the imperfect preservation of once complete radial bands. Reimann (1945) has suggested that color markings may sometimes be due to shell structure rather than pigmentation. In the present species, however, there can be no doubt that the preserved spots represent the original pigmentation. This peculiar color pattern has not been reported, insofar as I am aware, except in Devonian terebratuloids; it is not present in any living species.

The color spots of fossil terebratuloids are usually brown or maroon in color, but analogy to living forms suggests that the pigment was originally some shade of red. The stability of the pigment is truly remarkable, as attested by its preservation from the Devonian to the present. Even more remarkable is the fact that in one specimen silica has replaced the shell material in places without affecting the color markings. The same feature has been noted in completely silicified Permian terebratuloids (Pl. 87, figs. 14–19). Evidently silicification can proceed without solution or alteration of the coloring matter. The exact chemical nature of the color pigment is not known either in Recent or fossil brachiopods. Chemical analysis of the pigment of Recent terebratuloids and its comparison with fossil pigment suggests a means for the investigation of a little known phase of biochemical evolution, but has not yet been undertaken.

Genus MACLARENELLA Stehli, n. gen.

Genotype.—*M. maculosa* Stehli, n. sp.

Diagnosis.—Smooth Cranaeninae of subcircular to oval outline. Pedicle valve posteriorly flattened with a pronounced but broad sulcus developing anteriorly; valve longitudinally rather convex; beak erect; beak ridges slightly angular; foramen permesothyrid, labiate; deltidial plates conjunct. Brachial valve longitudinally strongly convex; transversely very strongly and angularly convex with the medial portion of the valve raised in a high fold. Lateral commissure strongly sinuate; anterior commissure strongly uniplicate.

Pedicle interior with a pedicle collar and strong dental plates. Brachial interior with a free, perforate cardinal plate extending as a plane between the socket plates; crura

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arising from the cardinal plate; loop short, dielasmoid.

Discussion.—*Maclarenella* represents an evolutionary divergence from the genus *Cranaena* with which there is virtual identity of internal structure. The principal difference between the two genera is in the conservative terebratuliform exterior of *Cranaena* and the cross sectionally triangular form of *Maclarenella* resulting from its pronounced fold and sulcus. As far as is presently known this genus did not give rise to any further evolutionary grades.

MACLARENELLA MACULOSA Stehli, n. sp.
Pl. 87, figs. 1–13

Diagnosis.—Moderate to large sized *Maclarenella* of subcircular to oval outline, almost equilaterally triangular in cross section, anterior commissure strongly uniplicate. Pedicle valve longitudinally slightly convex, transversely almost flat near the beak to strongly concave toward the front; sulcus deep and evenly rounded arising in the posterior third of the valve; beak erect to slightly incurved; beak ridges rounded; foramen of moderate size, permesothyrid; labiate; deltidial plates conjunct. Brachial valve strongly convex longitudinally; fold high and angular giving the valve high transverse convexity; fold angular but not otherwise distinct from the general curvature of the valve and becoming more rounded toward the front. The surface of both valves smooth or minutely marked by very fine growth lines and sometimes by obscure radial striae. Six to 12 radial rows of color spots are present, with the brachial valve normally bearing two or three more rows than the other. Pattern of spot arrangement concentric but each row cut at an angle by the growth lines, indicating that deposition of color is not synchronous in all bands.

Internal characters as described for the genus. The transverse band of the loop is broken in the specimen sectioned, but enough of the loop remains to show beyond doubt that it was a short dielasmoid type.

Measurements in mm. of five specimens:

Length	Width	Thickness
25	22	15
39	34	23
31	28	17
35	28	18
31		21

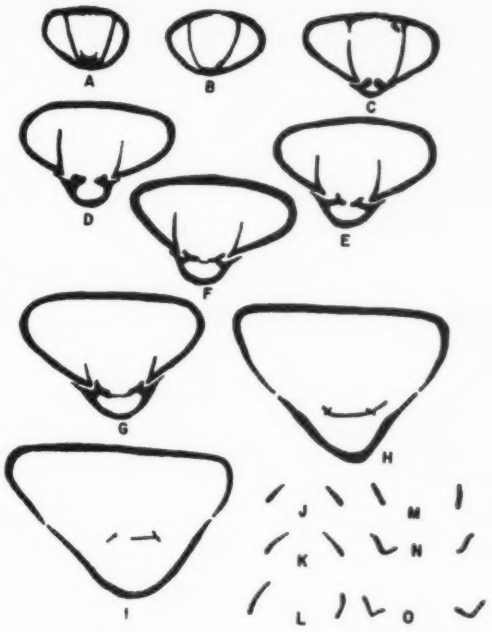

FIG. 1—Selected sections from a series of 74 ground from a paratype (×2¾). *A* (section 1), showing dental plates and a portion of the pedicle collar. *B* (section 2), showing dental plates only. *C* (section 8), showing the brachial valve in the region of the perforation of the cardinal plate, and muscle scars in the pedicle valve. *D* (section 13), showing the anterior margins of the dental plates and the perforation of the cardinal plate. *E* (section 15), a section at the anterior edge of the cardinal plate perforation. *F* (section 16), a section through the cardinal plate anterior to the apical perforation. *G* (section 23), a section at the anterior margin of the cardinal plate. *H* (section 32) showing the crura still united by a part of the hinge plate but free of the sockets. *I* (section 37), showing the initiation of the free loop. *J–O* (sections 41, 45, 53, 56, 59, 65), showing the development of the loop including the start of the transverse band which was broken in this specimen.

Remarks.—Two remarkably preserved specimens of this species were found by the writer in the collections of the California Institute of Technology. Their collector is unknown but locality data with the specimens indicate that they were collected from the "top of exposed Devonian 4–6 miles north of McMurray on Athabaska River." They are from the upper Middle Devonian Waterways formation. Of these two specimens one, a paratype, has been retained at

the California Institute of Technology (CIT 5947), the other, the holotype, has been presented to the U. S. National Museum (USNM 124225).

Through the kindness of D. J. McLaren two additional specimens were obtained, from beds in the upper part of the Waterways formation at the west end of Rocke Island, Athabasca River near Fort McMurray, Alberta. These two specimens are paratypes, and are housed in the collections of the Geological Survey of Canada (GSC 11,792 and 11,793). The only other specimens known to exist in collections were obtained from P. S. Warren. They are also to be regarded as paratypes and were collected from exposures of the Waterways formation along the east side of Athabaska River at the mouth of Horse Creek, one mile upstream from the mouth of Clearwater River. They are housed in the collections of the University of Alberta (Dv. 1311 and Dv. 1312). Specimen Dv. 1312 was sectioned to discover the nature of the interior, and is now represented by a series of 74 mounted collodion peels.

MANUSCRIPT RECEIVED JANUARY 6, 1955.

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EXPLANATION OF PLATE 87

Maclarenella maculosa Stehli, n. gen., n. sp.

FIGS. *1, 2, 4, 5, 7*—A beautifully color marked, but somewhat crushed specimen, CIT 5947; Waterways formation, 4 to 6 miles north of McMurray, Athabaska River, Alberta. *1, 2*, Brachial and pedicle exteriors. *4*, Anterior view showing pronounced uniplicate anterior commisure. *5, 7*, Posterior and lateral views. All ×1.

3, 12—Holotype, USNM 124225; locality same as for CIT 5947. *3*, Detail of beak region, ×3; specimen coated with ammonium chloride. *12*, Posterior view, uncoated, ×1.

6, 8–11—Lateral, anterior, posterior, pedicle and brachial views of CGS 11,792; Waterways formation, Rocke Island, Athabaska River, Alberta. All ×1.

13—Anterior view of largest known specimen, CGS 11,793, ×1. Locality same as for CGS 11,792.

Dielasma sp. Silicified Permian specimens retaining color markings. Getaway member, Cherry Canyon formation, Guadalupe Mountains, Texas.

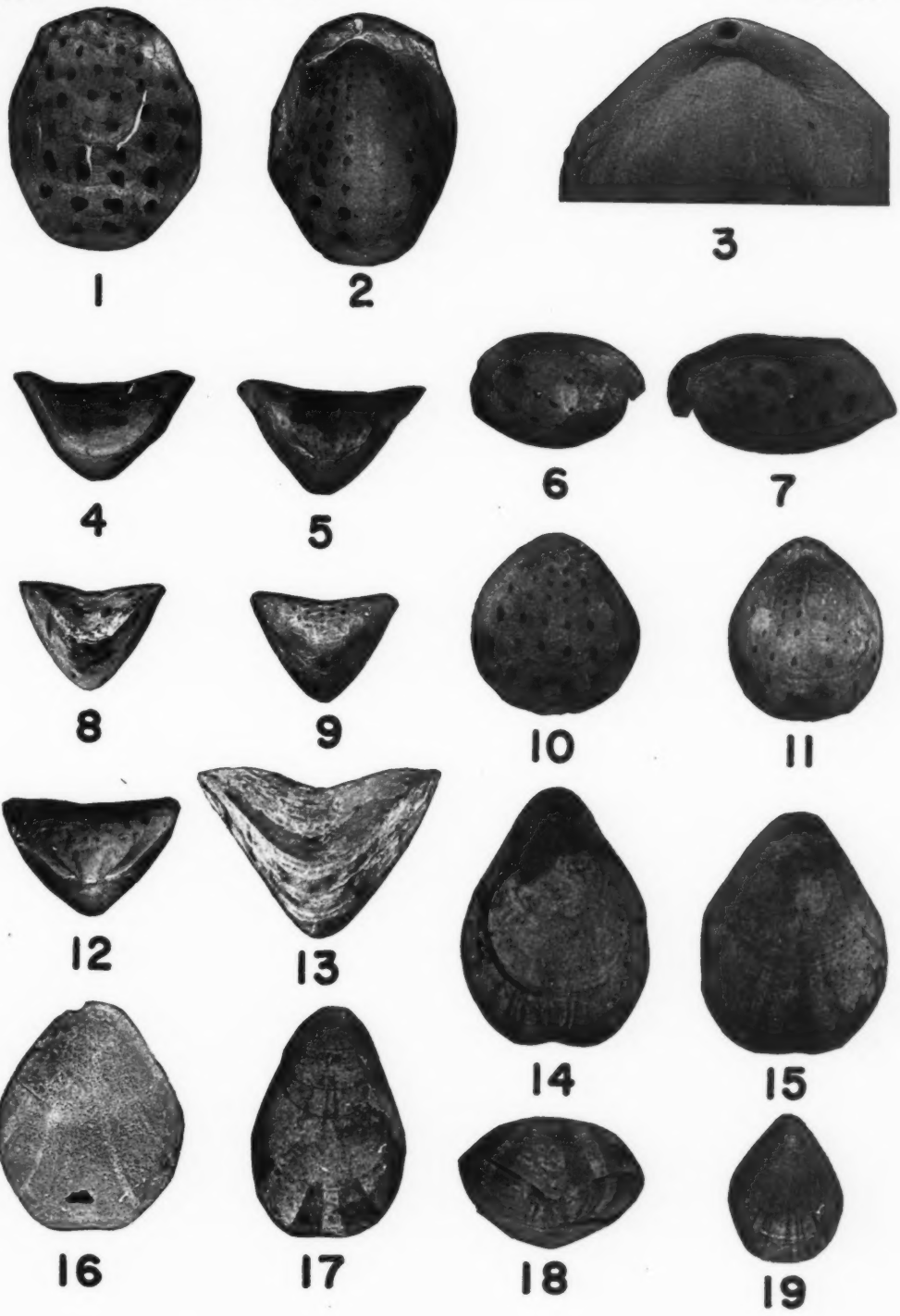
FIGS. *14, 15*—Brachial and pedicle views of CIT 5948/1, with color pattern preserved only at the margin, of brachial valve, ×1.8.

16—Pedicle view of CIT 5948/2, ×1.8.

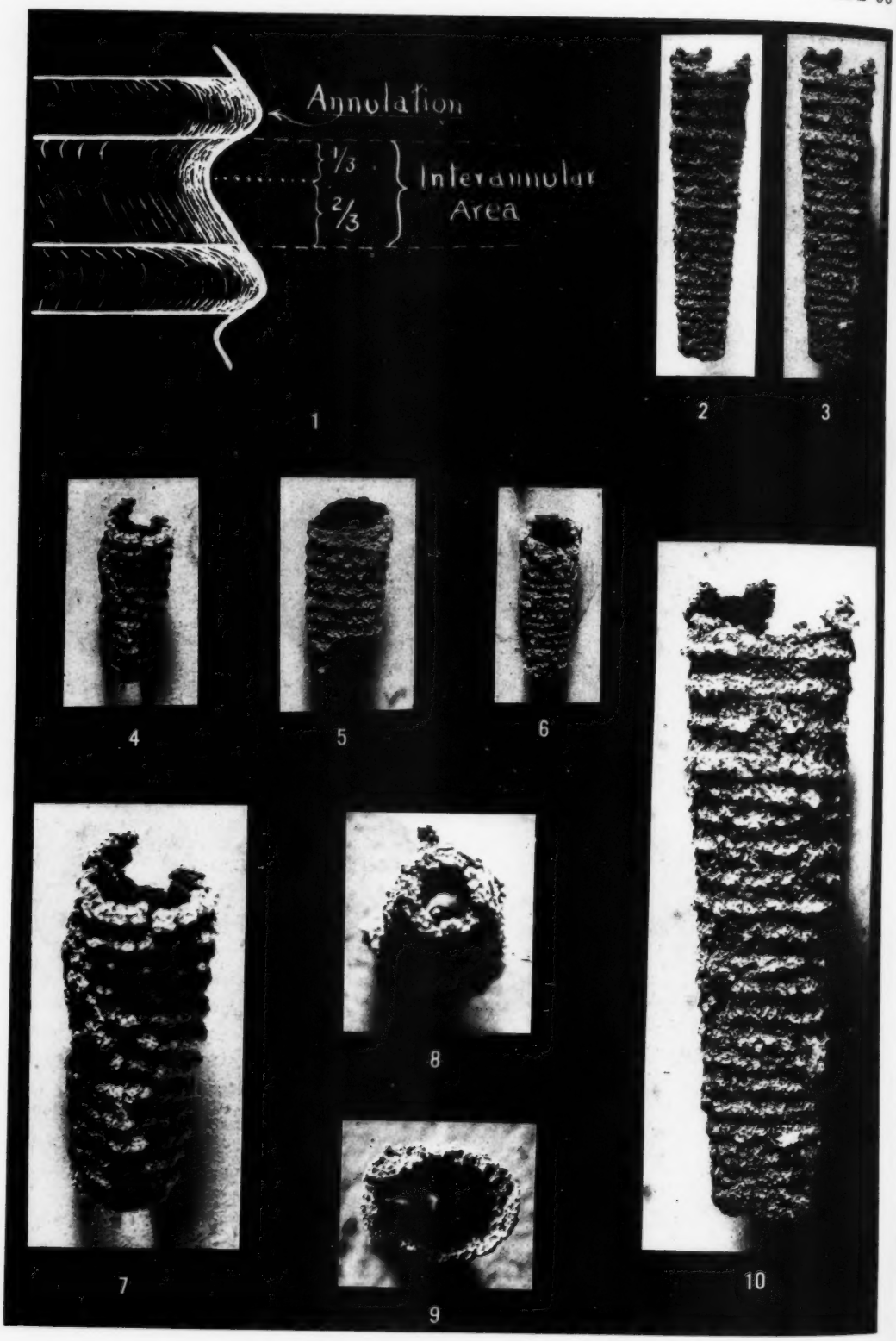
17—Pedicle view of CIT 5948/3, a specimen with unusually wide color bands, ×1.8.

18—Anterior view of CIT 5948/4 showing the asymmetry of color marking on the two valves, ×1.8.

19—Pedicle view of a smaller, delicately marked individual, CIT, ×1.8.



Stehli, Devonian and Permian brachiopod color patterns



Fisher and Young, Canadian tentaculitid

JOURNAL OF PALEONTOLOGY, VOL. 29, NO. 5, PP. 871–875, PL. 88, 1 TEXT-FIG., SEPTEMBER 1955

THE OLDEST KNOWN TENTACULITID—FROM THE CHEPULTEPEC LIMESTONE (CANADIAN) OF VIRGINIA

DONALD W. FISHER* AND ROBERT S. YOUNG
New York Geological Survey, Albany, N. Y.; Virginia Division of Geology, Charlottesville, Va.

ABSTRACT—A new tentaculitid, *Tentaculites lowdoni* Fisher & Young, n.sp., is described and illustrated from the Lower Ordovician (Canadian) Chepultepec limestone, near Fishersville, Augusta County, Virginia. This discovery is of significance as it extends the stratigraphic range of the Tentaculitidae; the lower limit previously being considered Middle Ordovician (Trentonian).

INTRODUCTION

EVER since Walch (1775, fig. 5) first illustrated the fossils that were subsequently assigned the name *Tentaculites* by Schlotheim (1820, p. 377), these curious organic remains have defied precise zoological assignment and thereby aroused the interest of paleontologists the world over. For a century and a half these fossils have variously been assigned to the Pteropoda, worms, Conulariida, Echinoderma, Brachiopoda, Scaphopoda, and Cephalopoda. To date, their classification remains as obscure as ever and it is regrettable that no further enlightenment can be presented here toward a certain taxonomic designation.

During the course of etching pieces (with hydrochloric acid) of Lower Ordovician Chepultepec limestone to obtain the silicified fauna, the junior author recovered several specimens which he provisionally identified as *Tentaculites*. These were subsequently sent to the senior writer for verification, as he is in the process of investigating the tentaculitids and hyolithids for the *Treatise of Invertebrate Paleontology*. Careful scrutiny revealed that the specimens in question were bonafide representatives of the genus *Tentaculites*. To find a true tentaculitid in strata as old as Lower Canadian was startling, to say the least!

Tentaculitids, despite their unknown biologic affinities, have proved to be useful guide fossils for the Silurian and Devonian periods especially and their remains profusely cover bedding planes in some formations. Tentaculitids have heretofore been unreported in strata older than that of Middle Ordovician (Mohawkian) age and even those were dubiously assigned to the genus *Tentaculites*. Re-examination of *Tentaculites flexuosa* Hall (from the Trenton limestone of N. Y.) and *Tentaculites obliquus* Bassler (from the Trenton [Hermitage] of Danville,

* Published by permission of the Director, New York State Museum and Science Service, Journal Series No. 6.

EXPLANATION OF PLATE 88

All specimens from the Lower Ordovician (Canadian) Chepultepec limestone, 3.5 miles northeast of Fishersville, Augusta County, Virginia

FIG. *1*—Diagrammatic representation, ×40, showing relationship of annulations and manner of pseudo-invagination of interannular area, producing an asymmetrical outline of the tentaculitid wall.

2, 3, 10—*Tentaculites lowdoni* Fisher & Young, n. sp., holotype; *2*, uncoated longitudinal view of N.Y.S.M. 10778, ×5; *3*, same, but coated with ammonium chloride; *10*, magnified longitudinal view of holotype, ×10.

4–9—Paratypes of *Tentaculites lowdoni* Fisher & Young, n. sp.; *4*, uncoated longitudinal view of N.Y.S.M. 10782, ×5; *7*, magnified view of same coated with ammonium chloride, ×10; *5*, coated longitudinal view of N.Y.S.M. 10781, ×5. *6*, coated longitudinal view of N.Y.S.M. 10784, ×5; *8*, coated apical view of N.Y.S.M. 10779, ×10, illustrating circular cross section and uniform wall thickness; *9*, coated apertural view of N.Y.S.M. 10783, ×10, illustrating elliptical outline and varying wall thickness owing to distortion of tentaculitid tube.

Ky.) by the senior author discloses that in both instances the forms are more properly referable to the genus *Cornulites*. Both species are noticeably curved, a condition atypical of tentaculitids, whereas *T. flexuosa* invariably occurs adhering to other objects and *T. obliquus* possesses annulations oblique to the axis of the tube. Both latter features are wholly alien to true tentaculitids. Faunal association and stratigraphic position authenticated the Chepultepec (Lower Canadian) assignment of *Tentaculites lowdoni*.

The junior author wishes to acknowledge the cooperation of G. Arthur Cooper, Jean Berdan, and William J. Sando, of the U. S. National Museum and U. S. Geological Survey, for aid in the identification of this and other Chepultepec fossils and in discussions of the stratigraphy of the Chepultepec limestone.

GEOLOGIC SETTING

The specimens are known from a single locality, 3.5 miles N 48° E of the Chesepeake and Ohio railway overpass on the Jefferson Highway (U. S. 250) at Fishersville, Augusta County, Virginia (Text-fig. 1). They occur in fine to medium textured limestones, dark gray on fresh fracture and weathering to a dull white. The outcrop is on the west limb of a minor anticline, on the west side of a local fault which runs northeastward through Fishersville. Fracture cleavage is well developed and this may account for the apparent lack of larger fossils.

Aside from the silicified *Tentaculites*, the outcrop yielded some cystid plates, too fragmental for identification, poor specimens of *Finkelnburgia* and some baffling objects, currently indeterminable. Approximately ¼ mile from the *Tentaculites*-bearing rock,

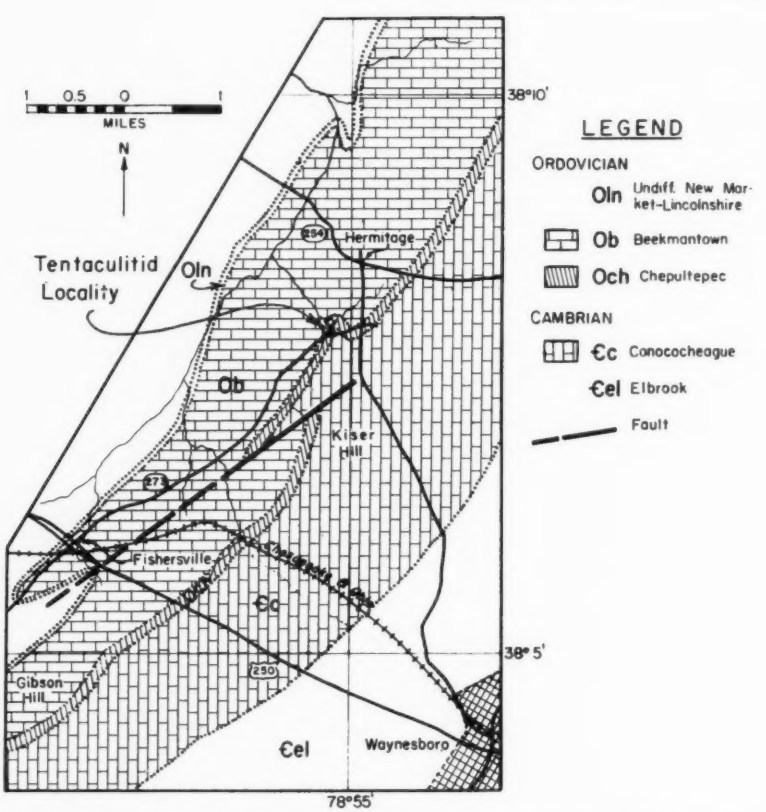


FIG. 1—Sketch map depicting geologic and geographic relationships in the vicinity of the site producing the silicified tentaculitid, *Tentaculites lowdoni* Fisher & Young, n. sp. (From I owdon, 1955).

in the same but faulted belt, is a fine section of Chepultepec limestone with a single bed of very well silicified *Finkelnburgia buttsi* Ulrich and Cooper. Associated with this are some non-silicified breviconic nautiloids of the *Dakeoceras* and *Levisoceras* types. Other outcrops have produced several species of *Finkelnburgia* and a fairly abundant cephalopod fauna, both presently under investigation.†

In Virginia, the Chepultepec limestone, named by Ulrich (1911, p. 638), succeeds the Upper Cambrian Conococheague limestone, or its facies equivalent, the Copper Ridge dolomite. It is, in turn, overlain by the "Beekmantown" group which contains *Lecanospira* and *Roubidouxia* both indicative of a Middle Canadian (Roubidoux) age. The overall similarity of the faunal assemblages of the Chepultepec of Virginia, the Stonehenge of Pennsylvania, and the Tribes Hill of New York, suggest contemporaneity or penecontemporaneity with the Gasconade of the Missouri section. Minor specific differences, or absence or presence of certain genera, may be attributed to minor ecological variations.

A composite faunal list of the Chepultepec limestone of the Appalachian Valley in Virginia as given by Butts (1940, p. 101) follows:

Brachiopoda

**Finkelnburgia buttsi* Ulrich & Cooper, and 2 other sp.
**Tetralobula delicatula* Ulrich & Cooper

Gastropoda

**Eccyliomphalus* sp.
**Gasconadia putilla* (Sardeson)
**Helicotoma uniangulata* (Hall)
**Ophileta* cf. *O. complanata* Vanuxem
**Ophileta*, a large form, possibly *O. grandis* Ulrich
Ozarkispira subelevata Ulrich & Bridge
**Sinuopea*, 2 sp.

Cephalopoda

Conocerina sp.
**Dakeoceras* sp.
**Ectenoceras* sp.
Hemithecella expansa Ulrich & Bridge
Levisoceras, 2 sp.
Robsonoceras ? sp.

Those genera preceded by an asterisk (*) are common to the Tribes Hill limestone of the Mohawk Valley, N. Y. *Clarkoceras*, found in the Chepultepec of eastern Tennessee, likewise is common in the Tribes Hill limestone.

† Subsequent to submission of this paper, *Tentaculites* has been found at other nearby Chepultepec localities.

SYSTEMATIC PALEONTOLOGY

Incertae Sedis
Family TENTACULITIDAE Walcott
Genus TENTACULITES Schlotheim, 1820

Genotype.—*Tentaculites scalaris* Schlotheim, 1820, p. 377, pl. 29, fig. 9b.

Diagnosis.—Thick walled, very gradually tapering narrow conical tubes with a circular cross section and terminating apically either acutely or in a gently expanded bulb. Surface displaying raised transverse parallel ridges lying at right angles to the axis of the tube. Occasionally, narrower transverse ornamentation occurs between the prominent ridges and sometimes longitudinal ornamentation is present. Tubes usually less than 30 mm. in length.

TENTACULITES LOWDONI Fisher & Young, n. sp.
Pl. 88, figs. 1–10

Holotype.—N.Y.S.M. 10778.
Paratypes.—N.Y.S.M. 10779–10784.
Formation and age.—Chepultepec limestone, Lower Ordovician (Canadian).
Locality.—3.5 miles northeast of Fishersville, Augusta County, Virginia.

Description.—This species is based on seven incomplete but adequately preserved specimens recovered by etching Lower Ordovician Chepultepec limestone in dilute hydrochloric acid. The specimens are imperfectly silicified and coarsely preserved so that delicate details, if originally present, are now lacking. The general morphologic features, however, are sufficiently shown to warrant assignment of a new species name.

The fossils are very gradually tapering straight tubes, incomplete apically and aperturally. The tubes are hollow, though it is doubtful whether the open cavity ex-

tended the entire length of the tube. Other species of *Tentaculites* possess solid apical terminations. All the types are circular in cross section, though N.Y.S.M. 10780 is somewhat flattened longitudinally causing the wall to thicken in the direction of the greater diameter and thin in the direction of the lesser diameter. This distortion is probably the direct result of the cleavage.

Regularly spaced annulations, elevated 0.16 mm. on the apertural extremity and 0.05 mm. on the apical extremity of the holotype, occur along the entire length of the tube. Annulations are prominent, subangular, with steeper side projected apically; the less gradual portion of the annulation is on the apertural side. The interannular distance diminishes almost imperceptably toward the apex. The interannular area is of particular interest. In profile it is an asymmetrical trough, the steeper portion toward the aperture occupying from one-third to two-fifths the total interannular distance. In combination with the annulations, the interannular areas produce the effect of a series of nested cones with their imaginary apices directed toward the aperture. There is a faint suggestion of interannular striations paralleling the annulations but this is observable in only a few instances. No longitudinal ornamentation is visible on any of the specimens.

Dimensions (in millimeters) of the seven specimens are tabulated below.

The constancy of thickness of the tentaculitid wall is particularly noteworthy as is the fact that the portion of tube preserved reveals the inner apertural diameter and the outer apical diameter to be essentially alike. The terms aperture and apex are utilized with full realization that the specimens do not actually retain the aperture and apex. Annulations on the apical extremities of paratypes 10780, 10783, and 10784 are so indistinct as to render measuring of the interannular distance impossible. This suggests proximity to the true apex. On the basis of diameter measurements coupled with number of annulations per millimeter and interannular distance, it is considered that the holotype (10778) is a young adult individual; 10781 the apertural portion of an older adult, whereas 10780 and 10784 represent near-apical portions of younger individuals. N.Y.S.M. 10782 is a central tubular portion of a young adult. Paratype 10783 is practically devoid of annulations and is believed to represent a cast of the interior of a tentaculitid tube.

Derivation of name.—The species is named for Mr. Jack Lowdon who, when a graduate student at the University of Virginia, made the initial discovery of these fossils.

Repository.—The holotype and six paratypes, upon which the description is based, are preserved in the type collection of the New York State Museum at Albany, N. Y.

Specimen no.	Length	Diameters				Wall Thickness	Inner-Annular Distance		No. of annulations per mm.
		Apertural		Apical			at aperture	at apex	
		Outer	Inner	Outer	Inner				
10778 (holotype)	9.0	2.3	1.6	1.5	0.73	0.34–0.37	0.52	0.35	3 (aperture) 4 (apex)
10779	5.1	2.2	1.5	1.4	0.68	0.34–0.37	0.37	0.31	4
10780	5.4	1.9–2.3	1.2–1.6	1.3	0.52	0.34*	0.37	indistinct	4
10781	5.6	2.4–2.7	1.7–2.0	2.0	solid	0.37	0.63	0.39	3
10782	4.7	2.3	1.6	1.6	0.84	0.34–0.37	0.44	0.37	3.5
10783	6.1	2.0	solid	1.3	solid	0.37	0.42	indistinct	—
10784	4.7	2.0	1.3	1.3	0.52	0.37	0.31	indistinct	4

* Shell thickness of this specimen exceedingly variable owing to abnormal thickening and thinning as a result of distortion.

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MANUSCRIPT RECEIVED MARCH 3, 1955

NOTICE ON ZOOLOGICAL NOMENCLATURE

Notice is hereby given that the possible use by the International Commission on Zoological Nomenclature of its Plenary Powers is involved in applications relating to the under-mentioned names included in Parts 5 of Volume 11 of the Bulletin of Zoological Nomenclature, scheduled for publication on May 31, 1955:

1. *Aucella* Keyserling, 1846 (Class Lamellibranchiata), validation of (pp. 158–166) [Z.N. (S.) 827].

2. *Muntiacus* (Class Mammalia) validation of, as from Rafinesque, 1815, with *Cervus muntjak* Zimmermann, 1780, as type species (pp. 167–169) [Z.N. (S.) 481].

Any specialist who may desire to comment on the foregoing applications is invited to do so in writing to the Secretary to the International Commission (Address: 28 Park Village East, Regent's Park, London, N.W.1, England) as soon as possible. Every such comment should be clearly marked with the Commission's File Number as given in the present notice.

Extracted from note from FRANCIS HEMMING, Secretary to the International Commission on Zoological Nomenclature, dated May 20, 1955

JOURNAL OF PALEONTOLOGY, VOL. 29, NO. 5, PP. 876–885, 1 TEXT-FIG., SEPTEMBER 1955

BELEMNITELLA PRAECURSOR, PROBABLY FROM THE NIOBRARA OF KANSAS, AND SOME STRATIGRAPHIC IMPLICATIONS[1]

J. A. JELETZKY
Geological Survey of Canada

ABSTRACT—A belemnoid guard in the paleontological collections of the University of Kansas belongs to the widespread and stratigraphically important European form *Belemnitella praecursor* var. *media* Jeletzky, 1955; it most likely belongs to the lowermost Campanian representatives of this form. The largely circumstantial evidence indicates that the guard came from the *Hesperornis* beds of the Niobrara formation in Kansas. This implies that the *Hesperornis* beds of Kansas are equivalent either to the upper part of the Telegraph Creek formation or to the Eagle formation of Montana and not to the upper part of the Colorado shale, as hitherto assumed. This makes it likely that the hiatus on the Great Plains, generally thought to be regional in extent and corresponding to the Telegraph Creek and Eagle formations of the region west of the Great Plains, decreases in magnitude to the east. Instead of one regional and prolonged break, several local and relatively short hiatuses could have occurred on the Great Plains during Niobrara time.

INTRODUCTION AND ACKNOWLEDGMENTS

THE guard of a belemnoid from an unknown locality preserved in the collections of the museum of the University of Kansas, Lawrence, has been loaned to the writer by Dr. Alfred G. Fischer. When examined, this large, fairly well preserved, though somewhat incomplete, guard proved to belong to the widespread and stratigraphically important Eurasian species *Belemnitella praecursor* Stolley, 1897. This species has never previously been reported from the Upper Cretaceous rocks of North America.

Belemnitella praecursor has been recently revised by Jeletzky (1955). This makes it unnecessary to discuss the concept of this species, its stratigraphical and geographical range, and stratigraphical importance in the body of this paper.

For the reasons fully discussed below the writer is convinced that the guard in question comes from the western interior region of the United States and was most likely collected from some part of the *Hesperornis* beds of the Smoky Hill member of the Niobrara formation of Kansas. It is realized, however, that the largely circumstantial evidence, which has led him to this conclusion, may appear inconclusive to some colleagues. Such possible doubts about the identification of this Eurasian species in North America deserve most careful consideration. The acceptance of the writer's conclusions would, indeed, necessitate the revision of certain time honoured and generally accepted stratigraphic concepts. The writer considers, however, that this report of *Belemnitella praecursor* in North America, together with its possible stratigraphical implications, serves a useful purpose regardless of whether or not the writer's conclusions will be immediately accepted. It is, indeed, necessary to bring it to the attention of paleontologists and geologists concerned with these problems and so to induce them to look for additional information in the course of their field investigations. During the past three years the writer has tried without success to obtain additional specimens of belemnoids from the Niobrara formation of Kansas.

The writer gratefully acknowledges the loan of the specimen and the information about it given by Dr. Alfred G. Fischer, formerly of the University of Kansas, Lawrence, now with the International Petroleum Company, Talara, Peru. Special thanks are due to Dr. John B. Reeside, Jr.,

[1] Published by the permission of the Director-General of Scientific Services, Department of Mines and Technical Surveys, Ottawa, Canada. The Geological Survey of Canada accepts no responsibility for statements or conclusions appearing in this paper, which deals entirely with foreign fossil material.

of the U. S. Geological Survey for stimulating discussion of the stratigraphical problems involved. Thanks are due to Mr. E. Elliott of the Photographic Division, Geological Survey of Canada, who prepared the photographs used in this paper.

BELEMNITELLA PRAECURSOR Stolley, 1897, var. MEDIA Jeletzky, 1955
Text-fig. 1a–c

Belemnitella praecursor, JELETZKY, 1948, pp. 344–345 (only the specimens of Blackmore not those of Sharpe and Jukes-Browne!), fig. 5a–b.
Belemnitella praecursor, n. var. JELETZKY, 1951, pp. 83–85, pl. 1, figs. 2a–b.
Belemnitella praecursor var. *media* JELETZKY, 1955, pl. 1, figs. 2, 3, 4; pl. 2, fig. 4; pl. 3, fig. 1–3.

Description.—Guard long, moderately stout, subcylindrical in ventral aspect. In lateral aspect it tapers gradually all the way down from the alveolar edge to the point about 15 to 20 mm. above the broken off apical end of the guard. At this point the tapering increases markedly down to the fracture mentioned above. It is believed that some 25 to 30 mm. of the guard were originally present below this latter.

The uppermost alveolar part of the guard (see Text-fig. 1a-c) is badly crushed and has consequently lost its original outline. It is assumed, however, that the flattening of the ventral side of the guard disappears here and that the alveolar cavity near its upper edge had originally a nearly circular cross section, or an oval cross section with the dorso-ventral diameter predominating. This is made especially probable by the comparison of the cross sections over the uncrushed, posterior portion of the guard. Indeed, the values of both diameters remain pretty nearly equal all the way from the apical fracture of the guard to the level of its embryonic bulb, despite the fact that the ventral surface of the guard shows a distinct dorso-ventral flattening throughout this interval. Then, over the uncrushed lower portion of the alveolar part of the guard, the ventral diameter begins to prevail over the lateral one.

The dorsal surface of the guard protrudes markedly in its alveolar third between the converging broad and rounded dorso-lateral depressions. This feature increases progressively toward the alveolar edge of the guard. The posterior two-thirds of the guard are more rounded, the dorso-lateral depressions become more and more indistinct toward the apical end and lose their identity about three-fifths of the way down from its alveolar edge.

Both sides of the guard show distinct and typically *Belemnitella*-like double dorso-lateral grooves. In the lower two-fifths of the guard these are cut into the evenly rounded surface of the guard. Further up toward its alveolar part they gradually transform themselves into broad and rounded dorso-lateral depressions and are lost in these latter about half way up from the broken off apical end of the guard. It should be noted, however, that on the left side of the guard the broad dorso-lateral depression seems to be subdivided in two by a low indistinct ridge raising from its bottom, yet this latter could not be connected with the double dorso-lateral grooves on its posterior part.

As far as visible on the partially corroded surface of the guard, the double dorso-lateral grooves run more or less parallel to and at the distance of about 2.0 mm. from one another, without forming any apprehensible wave-like undulations. On the right side of the guard, however, the distance between the dorso-lateral grooves increases to 2.5–3.0 mm. just above the apical fracture of the former. Here an additional fainter groove is inserted between the former two. On the left side of the guard the course of the dorso-lateral double grooves is nearly obliterated by the corrosion of the surface of the guard and by a series of closely spaced, more or less parallel, longitudinal scratches apparently caused by rough handling of the specimen during its excavation or preparation, or by another similar secondary cause. Few weak vascular imprints branch off the double dorso-lateral grooves in the apical third of the guard both toward its ventral and dorsal sides. As far as visible, the angle between all these vascular imprints and the double dorso-lateral grooves does not exceed 30°, while generally averaging 15 to 20 degrees. Irregularly bent, single, lateral grooves are present on both sides of the guard in its upper half. Only that on the left side, however, is well preserved. Few weak, vascular imprints branch off these lateral grooves

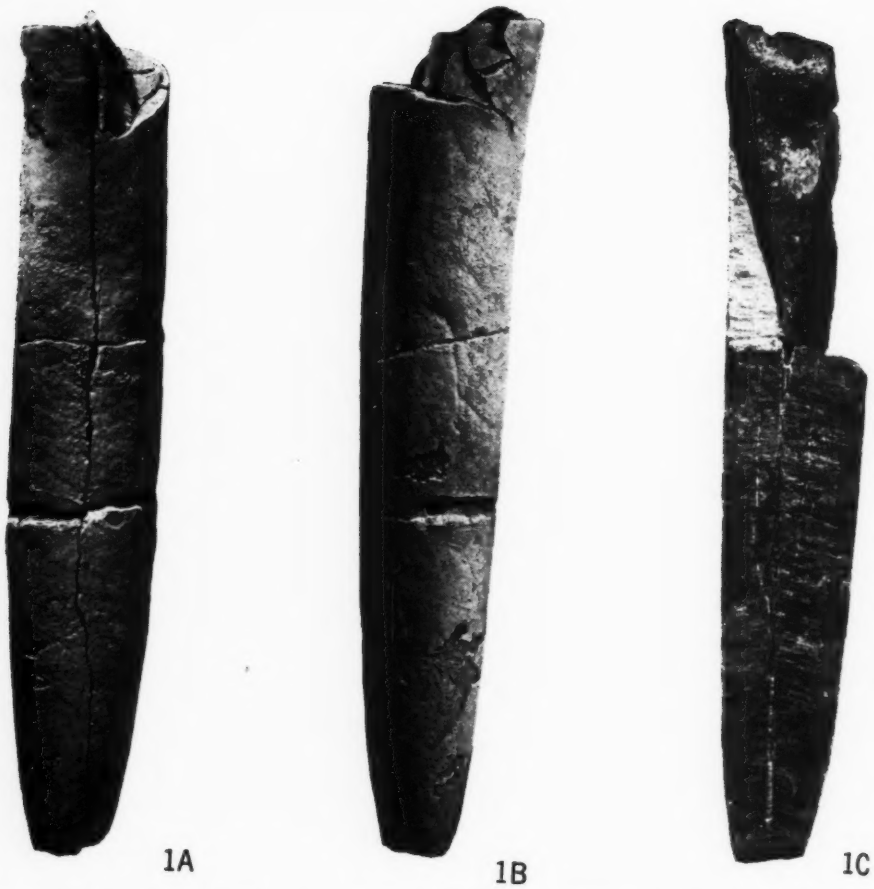

FIG. 1—*Belemnitella praecursor* Stolley, var. *media* Jeletzky, 1955. University of Kansas coll. no 3979. Upper Cretaceous. Colorado. All figures are about one eight larger than the original.

Formation and locality unknown; the writer believes that this guard is from the *Hesperornis* beds (=yellow chalk) of the Niobrara formation. The guard is most likely from the equivalents of some part of the zone of *Diplacmoceras bidorsatum* (=lowermost Campanian).

1a, Ventral view; *1b*, lateral view; *1c*, the same specimen split longitudinally to show the character of ontogeny, depth of the alveolus, Schatsky index, and the outline of the ventral fissure (painted black).

toward the ventral side of the guard and also toward broadly rounded, shallow dorsolateral depressions. Further branching of these vascular imprints is insignificant, just as it is the case with the main vascular branches on the apical third of the guard. Therefore only a widely spaced mesh of weak secondary vascular imprints is present on its ventral side. In addition to vascular imprints, weak, short, and somewhat irregularly bent longitudinal markings and striae are observable here and on both flanks of the guard. Its dorsal side, wherever not corroded, is practically smooth, except for a very few faint vascular imprints on the posterior third. Around the ventral fissure the surface of the guard is devoid of any vascular imprints and only shows few, extremely delicate, faint longitudinal striae. These are only visible by certain arrangement of light.

The thickness of the alveolar wall at its upper edge does not exceed 0.5 to 1.0 mm., which asserts that the guard is nearly com-

plete at its alveolar end, yet the preserved part of ventral fissure is rather short; it does not exceed 14 mm. in length.

The depth of the alveolus is about 43 mm. as compared with the total preserved length of the guard of about 103 mm. and its estimated total length of about 120–125 mm. Thus the alveolus would amount approximately to 0.35 of the estimated length of the guard.

The guard was split in such a manner as to make an exact measurement of the alveolar angle impossible, still it is sufficiently apparent that this latter (in dorso-ventral plane) is somewhere between 20 and 25 degrees, which is typical of the genus *Belemnitella* d'Orbigny 1842 emend. Jeletzky, 1941, and of the species *B. praecursor* Stolley. The bottom of the ventral fissure forms a very long, practically straight line running very oblique to the inner wall of the alveolus. The angle between the two amounts only to about 10 degrees. Therefore the ventral fissure reaches the surface of the guard about 28 mm. above the embryonic bulb which accounts for the insignificant length of the ventral fissure on the ventral surface of the guard. The distance between the embryonic bulb and the beginning of the ventral fissure on the inner wall of the alveolus, amounts to 9.0 (8.5) mm. as measured on both halves of the guard. The appearance of the conotheca is typical of *B. praecursor* (see Jeletzky, 1955). It should be noted, however, that the shagreen-like ornamentation of the conotheca near the apex of the alveolus is relatively strongly developed.

The ontogeny of the guard was only observed on the split surface where its details are none too clear. It is, however, apparently of a *Belemnitella*-like type (as opposed to *Belemnella* Nowak). The smallest juvenile guard observable (Text-fig. 1c) appears to be a slender, long, but not needle like, body, the dorso-ventral outline of which is similar to a shoe tack. Just below the embryonic bulb, it seems to be 1.0 to 1.5 mm. wide and some 7.0 to 8.0 mm. long (possibly less than that). The next juvenile guard observable is about 30 mm. long below the embryonic bulb and some 12 mm. wide at its level. It has already the general outline of an adult guard in its dorso-ventral plane and already shows an imperfectly developed mucro (Text-fig. 1c). All the subsequent juvenile guards are almost invisible and their outlines could not be restored. It is apparent, however, that the general character of the ontogeny of the specimen here discussed is essentially similar to that of the specimens of *B. praecursor* Stolley figured by Jeletzky (1948, fig. 5b, pl. 1, fig. 2a).

Age and subspecific relationships.—From the comparison of the description and figures (Text-fig. 1a–c) of the here discussed *B. praecursor* guard with those of the Eurasian representatives of the species given by Jeletzky (1955) it is evident that the former falls well within the known range of subspecific variation of *B. praecursor* Stolley var. *media* Jeletzky, 1955. Accordingly the writer assigns the Kansas guard to the above variety of *B. praecursor* Stolley s. l.

With regard to the size and outline of the guard and the character of its vascular imprints, the Kansas specimen of *B. praecursor* var. *media* has its place about half-way between the typical representatives of *B.p.* var. *media* (see Jeletzky 1955, pl. 57, figs. 2a-c, 4a-b) and the distinctly sculptured, moderately stout passage forms between this variety and *B. mucronata* (Schlotheim) mut. *senior* Nowak s. s. (see Jeletzky, 1955, pl. 58, fig. 1a-c). The presence of an imperfectly formed mucro already in the middle stages of ontogeny of Kansas specimen is also suggestive of a "high" rather than "low" form of the species. This feature and the large size of the Kansas guard of *B. praecursor* var. *media* virtually exclude its reference to the upper Santonian representatives of the species, as these latter are not known to reach large dimensions or to possess blunt, mucronate apical ends of the guard.

At the same time a fairly short ventral fissure, nearly smooth surface of the guard around this latter, and a long, practically straight bottom of ventral fissure are more suggestive of the "low" form of the species. The distinctly ornamented surface of the conotheca, though not very diagnostic if considered alone, resembles more closely the forms of *B. praecursor* encountered in the middle part of its zone.

The above described combination of diagnostic features in Kansas specimen indicates

its lower Campanian age, almost to the exclusion of the upper Santonian one, since such large, relatively strongly sculptured forms of *B. praecursor* Stolley s. l. are not known to occur as low as that. The occurrence of the earliest (upper Santonian) forms of this species in the western interior sea of North America is utterly unlikely also in view of their restricted distribution in Eurasia (see Jeletzky, 1955). These forms are only known from the Russian boreal basin, except for the few questionable finds in the Baltic region. The upper Santonian forms of *B. praecursor* Stolley s. l. seem to be absent already in northwestern Germany and in England.

Therefore it is assumed that the Kansas guard of *B. praecursor* Stolley s. l. was most likely collected from the equivalents of some part of the zone of *Diplacmoceras bidorsatum* (Roemer), though its somewhat younger age cannot be ruled out.

ORIGIN, STRATIGRAPHICAL HORIZON, AND LOCALITY OF *B. praecursor* VAR. *media*, AND THE AGE OF *Hesperornis* BEDS

Before discussing the stratigraphical importance and implications of the above described guard of *B. praecursor* Stolley var. *media* Jeletzky, it is imperative to investigate fully the problem of its origin, stratigraphical horizon, and locality, as the specimen is unfortunately very imperfectly labeled. Dr. A. G. Fischer has, indeed, informed the writer, in the letter dated May 16, 1951, that the guard is entered in the record book of the museum of the University of Kansas as "Belemnites, U. K., Colorado" and that there are no data available about its exact locality, formation and collector. In the writer's opinion the use of the word "Colorado" in the label makes it quite evident that the guard has been collected somewhere within the western interior region of North America, as the use of the term is restricted to this region. It is important to stress that this scanty information provided by the label taken together with the lithological character of the rock filling out its alveolus (see below) are deemed to be sufficient to dispel the possibility of the guard being of the Eurasian origin. The writer, who has seen specimens of *Belemnitella praecursor* Stolley s. l. and the rock samples of its zone from nearly every European and Russian locality of this species, simply does not know of any rocks lithologically similar to the orange or bright yellow chalky rock of the *Hesperornis* beds in the zone of *Belemnitella praecursor* anywhere in this region. It should further be noted in this connection that *B. praecursor* is a rare to very rare form throughout western and northern Europe. Only in England does it become fairly common in the area of Salisbury (Jeletzky, 1955). Therefore it is very unlikely that the guard here discussed could reach North America as a part of an exchange collection. As far as Russia is concerned, exchange of the paleontological collections between that country and the United States was virtually nonexistent in the older days.

With regard to the locality and the stratigraphical horizon of the guard, it is of course impossible to decide from the label alone whether the word "Colorado" stands for the Colorado group or for the state of Colorado. The writer assumes, however, that the first alternative is correct and that the guard represents one of the specimens of belemnites recorded by Williston (1897, pp. 241–243) from the *Hesperornis* beds of the Niobrara formation of Kansas. His reasons are the following:

(1) All the upper part of the alveolus of the guard is filled up with a calcareous, chalky, fairly coarse, fragmentary rock, rich in organic remains resembling fish scales. This rock is of light yellow to rusty-yellow color throughout. The fractured uppermost alveolar part of the guard overlaps the upper part of the alveolous filled up with this rock in such a way (Text-fig. 1a-1b) as to exclude the possibility of this latter being silted into alveolus after the guard became exposed by the erosion. The inner part of the alveolar cavity is filled up with the the coarse crystalline calcite.

The lithological character of the rock filling up the alveolus indicates, in the writer's opinion, that the guard is from *Hesperornis* beds of the Niobrara formation. Williston (1897, p. 239) states positively that:

> the yellow color with its varying shades of red, where much exposed, is confined to the upper beds [of the Niobrara formation] and the line of

separation is very easily traced from the Smoky Hill East of Monuments Rocks to the Saline north of Wa Keenley, and thence to the South Fork of the Solomon near Lenora. Not only is the color line easily traced, but the fossils contained in them are characteristic For convenience I will call them the Hesperornis beds and Rudistes beds.

Also Elias (1931, p. 42) accepts the stratigraphical divisions of Williston (1897).

(2) Jeletzky (1955) has shown that because the complete biozone of *Belemnitella praecursor* Stolley s. l. is known, this species cannot occur in any beds older than upper Santonian in age. In Kansas the stratigraphic position of the equivalents of the upper Santonian zone of *Uintacrinus* is sufficiently well known. This practically worldwide zone lies here within the Niobrara formation. According to Williston (1897, p. 242): "all the specimens [of *Uintacrinus*] of which I have any knowledge have come from the vicinity of Elkader, in the valley of the Smoky Hill, in the horizon just below the yellow chalk." Elias (1931, p. 42) also point out that *Uintacrinus socialis* Grinnell in Kansas is confined to the top of *Rudistes* beds below the yellow, buff or reddish chalk of *Hesperornis* beds. There are no records of *Marsupites* ever having been found together with *Uintacrinus socialis* Grinnell in any of the Kansas localities of this latter species. Therefore it would appear more likely that the top part of the *Rudistes* beds of Kansas corresponds to the lower subzone (*Uintacrinus* subzone of the European zonal scheme) with *Uintacrinus*, which is of pre-Telegraph Creek age (see Reeside, 1923, p. 25; Cobban & Reeside, 1952, correlation table, p. 1019). The overlying *Hesperornis* beds of Kansas are therefore likely to correspond to the uppermost beds of the upper Santonian with *Marsupites*, *Uintacrinus*, and *Desmoscaphites bassleri* (Telegraph Creek fauna; see Reeside, 1923, p. 25; Cobban & Reeside, 1952, correlation table, p. 1019). In terms of the European zonal scheme, this fauna corresponds precisely with the *Marsupites* subzone of the Santonian stage.

It has already been pointed out in the previous pages of this paper that the morphological similarites of the Kansas guard of *B. praecursor* var. *media* are with the forms of the variety occuring in the zone of *Diplacmoceras bidorsatum* of Europe. Therefore this guard could hardly have been collected even in the uppermost Santonian rocks with *Marsupites* and *Uintacrinus*. This could indicate that, unless the top part of the *Rudistes* beds is already of the Telegraph Creek age (*Marsupites* subzone), the *Hesperornis*-beds correspond not only to the Telegraph Creek formation but to the part or all of the Eagle formation as well. It should be kept in mind, however, that as far as southern Montana is concerned, the research of Reeside (1923, pp. 25, 28) has shown that only the lower part of the Telegraph Creek formation is definitely of the uppermost Santonian age. This is proven by the joint occurrence of *Uintacrinus* and *Marsupites* in the lower beds of the Telegraph Creek formation and by the solitary occurrence of the *Uintacrinus socialis* Grinnell in the upper beds of the underlying Niobrara formation in southern Montana. The higher beds of the Telegraph Creek formation in southern Montana could therefore easily be already of the lowermost Campanian age (=zone of *Diplacmoceras bidorsatum*). Should this assumption be correct, it would not be necessary to postulate the correlation of the upper part of the *Hesperornis* beds of Kansas with the Eagle formation of Montana as *B. praecursor* var. *media* could have been collected from the equivalents of these upper beds of the Telegraph Creek formation. Only future investigations can show which of the above assumptions is correct, but this is immaterial for our argument. In any case it appears to be evident that the Kansas guard of *B. praecursor* var. *media* could hardly have been collected from any older rocks of the state than the *Hesperornis* beds of the Niobrara formation.

(3) The possibility that the guard here discussed could have been collected from the overlying Pierre shale, which is of the lower Campanian age at least in its lowermost part, is contradicted by the lithological character of the rock preserved in the alveolus of the guard. Already Elias (1931, pp. 29–30) states postively that no calcareous rocks lithologically similar to the yellow chalk of the *Hesperornis* beds are known to occur in the overlying Pierre shale of Kansas. Furthermore, as far as the writer

knows, Pierre shale of all the neighboring states of the United States western interior region also lacks any rocks lithologically similar to the yellow chalk of the *Hesperornis*-beds.

The sum total of the above evidence makes it virtually certain, in the opinion of the writer, that the Kansas specimen of *Belemnitella praecursor* var. *media* was collected from some part of the *Hesperornis* beds of Kansas.

UPPER AGE LIMITS AND CORRELATION OF THE NIOBRARA FORMATION

The above conclusion about the locality and stratigraphical horizon of the Kansas guard of *B. praecursor* var. *media* is of great interest and stratigraphical importance. It indicates that the *Hesperornis* beds of Kansas are equivalent to the uppermost Santonian and to the lower zone of the lower Campanian stage of western Europe rather than to the lower part of the Santonian stage of the same region as it has been hitherto generally assumed (see Cobban & Reeside, 1952, correlation table, pp. 1015, 1019, 1024–25, 1029). This conclusion checks well with the above discussed occurrence of *Uintacrinus socialis* in the top part of the *Rudistes* beds of Kansas some 300 feet below the upper limit of the Niobrara formation (see Elias, 1931, pp. 42–43). The exact position of the boundary line between Santonian and Campanian stages within the Niobrara formation of Kansas cannot be determined until the exact position of the bed with *Belemnitella praecursor* var. *media* within the succession of the *Hesperornis* beds is established. It appears to be evident, however, that the upward extension of the Niobrara formation of Kansas is greater than it was hitherto assumed.

In the literature, the Niobrara formation of the Great Plains of the United States is nearly always considered to be of the Coniacian and lower Santonian age (see Reeside, 1923, pp. 25, 28; Stephenson & Reeside, 1938, pp. 1631, 1637; Reeside, 1944; expl. of the map; Cobban, 1951, pp. 2195–2198; Cobban & Reeside, 1952, correlation table, pp. 1015, 1019, 1024–25, 1029). Accordingly the Niobrara formation is traditionally correlated with the upper part of the Colorado shale of the region west of Great Plains (Montana, Wyoming) but not with the Telegraph Creek and Eagle formations of this region. Only Elias (1931, correlation table opposite p. 130) has correlated the *Hesperornis* beds with the Telegraph Creek formation, which he regards as upper Santonian. Elias (1931, pp. 76–77) also points out that the Niobrara formation may be partly equivalent to the Pierre shale of other areas.

To explain the total lack of equivalents of the Telegraph Creek and Eagle formations and faunas all over the Great Plains the presence of a regional erosional gap of considerable magnitude has been postulated between the top of the Niobrara formation and the bottom of the Pierre shale all over this vast region (see Reeside, 1923, p. 28; Stephenson & Reeside, 1931, 1637; Reeside, 1944, expl. to the map; Cobban & Reeside, 1952, correlation table, pp. 1015, 1019, 1024–25, 1029). This erosional gap was thought to embrace all the time equivalents of the Telegraph Creek and Eagle formations of the region west of Great Plains or, in other words, most of the upper Santonian and lower Campanian stages of Western Europe.

It would seem to the writer that the above conclusions are not based on sufficient faunal evidence. The chalky rocks of the Niobrara formation are, indeed, notoriously poor in diagnostic facies-independent fossils, which would permit its detailed correlation with the shaly facies of the upper Colorado shales or with the sandstones of the Telegraph Creek and Eagle formations (see Elias, 1931, pp. 42–43; Cobban, 1951, p. 2192; Cobban & Reeside, 1952, p. 1024). This seems to be particularly true of the Niobrara formation of Kansas. The following few occurrences of the diagnostic fossils in the chalky Niobrara formation of the Great Plains certainly do support the above dating of its upper time limit. They occur, however, either along the western border of the Great Plains region or at any rate west of Kansas. As mentioned in the previous pages of this paper, the Niobrara formation of southern Montana does not extend upward above the *Uintacrinus* subzone (see Reeside, 1923, pp. 23, 28). The same appears to be true of the Black Hills area (see Cobban, 1951, pp. 2195–2198), although no diagnostic fossils have been

found in the chalky Niobrara of this area and the correlation with the upper Colorado shales appears to be based on lithological correlation alone. Dane, Pierce, and Reeside (1937, pp. 220–224) have shown that the Niobrara formation of the eastern Colorado north of Arkansas River is lithologically similar to the Niobrara formation of Kansas. These authors have even retained the Kansas member terms: Fort Hays limestone (renamed Hays limestone) below, and Smoky Hill member above for the area investigated by them. The following diagnostic fossils were recorded from the Smoky Hill marl member of the Niobrara formation by the authors mentioned above: *Inoceramus deformis* Meek?, *Inoceramus* aff. *I. stantoni* Sokolow?, *Ostrea congesta* Conrad, *Baculitis codyensis* Reeside. In addition following diagnostic fossils are quoted as collected by the late Prof. I. A. Keyte from a horizon near the top of the Smoky Hill member: *Baculites asper* Morton, *Baculites codyensis* Reeside, *Scaphites ventricosus* Meek and Hayden with several varieties, *Scaphites vermiformis* Meek and Hayden, *Texanites* cf. *T. pseudotexanus* Grossouvre. G. K, Gilbert collected a very large specimen of *Inoceramus undulatoplicatus* Roemer, from the upper part of the Niobrara northwest of Pueblo. Therefore the upper time limit of Niobrara formation in eastern Colorado does not seem to be much above the bottom of Santonian stage. Assuming that the above fauna was collected from its very top, and that no more faunas are present in this area below the bottom of Pierre formation, one might even doubt whether any beds younger than upper Coniacian are included in the Niobrara formation of the eastern Colorado. The presence of any erosional gap between Niobrara and Pierre formations is not mentioned by the above authors.

As long as there was no conflicting paleontological evidence available, it has been only natural to use the above mentioned occurrences of the diagnostic fossils in the chalky facies of the Niobrara formation for the dating of its upper time limit throughout the vast region of the Great Plains. Hence, it was assumed that the top beds of the Niobrara chalky marls of Kansas and other states occupying the eastern part of this region are also of the lower Santonian age. The paleontological evidence presented in the previous pages of this paper indicates, however, that at least in Kansas the chalky Niobrara formation represents a considerably wider time interval than the same formation in the eastern Colorado, northern Black Hills, and southern Montana. It would appear now that the stratigraphically narrower ranges of the chalky and marly facies of the Niobrara formation of the last mentioned areas have been taken to represent the maximum time extent of this formation and used for the correlation of the whole of this formation with the upper part of the Colorado shale of Montana, Wyoming, and northern Great Plains. Actually, however, the chalky facies of the Niobrara formation of Kansas appears to extend well into the lower Montana time; its uppermost beds correponding either to the upper beds of the Telegraph Creek formation or even to the lower part of the Eagle formation.

The above discussion indicates that the chalky and marly facies of the Niobrara formation has reached its maximum known time range in Kansas. From this area it appears to pinch out gradually toward west and north. This pinching out was naturally recognized by all authors, who have dealt with the subject. Its extent, however, and the circumstance that the upper Niobrara of Kansas is equivalent to certain lower parts of Montana group of Montana and of the northern Great Plains does not seem to be generally recognized by anybody except Elias (1931, p. 76–77; correlation table opposite p. 130), who was quite aware of it.

Concerning the regional erosional gap between Niobrara and Pierre formations in Kansas and elsewhere on Great Plains no definite conclusion is possible. The above paleontological evidence, taken together with the results of Elias (1931), make the existence of any such regional and prolonged break in sedimentation as postulated by Stephenson and Reeside (1938), Reeside (1944), and Cobban and Reeside (1952) somewhat doubtful for the eastern part of the Great Plains region. It appears to be obvious that at least in Kansas this hiatus could not be nearly as prolonged as assumed

by the above authors. It would seem possible to the writer that the break in sedimentation between Niobrara and Pierre diminishes gradually toward east. Such a decrease of the hiatus away from the then active geosynclinal belt of the Rocky Mountains is to be expected. It might also be that more than one local and short interruption of sedimentation has occured on Great Plains at that time. Due to the paucity or total lack of the index fossils of the Telegraph Creek and Eagle faunas in this region the nature of these hiatuses could not be recognized and they gave rise to the assumption of a regional and prolonged break in sedimentation between Niobrara and Pierre formations all over Great Plains.

PALEOZOOGEOGRAPHY

The occurrence of *B. praecursor* var. *media* somewhere in the *Hesperornis* beds of Kansas implies a sufficiently easy connection between the Upper Cretaceous sea of the western interior of North America and the boreal seas of Eurasia, where this species is known to be aborigenous (Jeletzky, 1955). The exceptionally wide (practically worldwide) distribution of somewhat earlier to contemporary (with the early forms of *B. praecursor*) species of floating crinoids *Marsupites* and *Uintacrinus* agrees very well with this conclusion. The same applies to the almost circumboreal distribution of *Scaphites hippocrepis* Dekay, which is about contemporary with the lower Campanian forms of *B. praecursor* s. l.

At an earlier date the writer (Jeletzky, 1950, p. 21–25) was able to show that *Actionocamax*, *Inoceramus*, and *Scaphites* faunas of the western interior of Canada indicate as easy marine connection of the western interior seas of North America with those of the Arctic and northern Eurasia at least from the Turonian to upper Santonian ages. Recently the first representatives of *Belemnitella* sp. indet. apparently belonging to *B.* ex gr. *B. propinqua* (Mob.) or *B.* ex gr. *B. mirabilis* Arch. have been found in East Greenland (Jeletzky in Donovan, 1954, pp. 13–14, 27). The as yet unpublished studies of the writer of the Colorado *Actinocamax* of Montana also point in the same direction. Therefore it is logical to assume that also *B. praecursor* Stolley s. l. reached Kansas via Canada and the Canadian Arctic archipelago. The writer is, however, still doubtful about this. *B. praecursor* is, indeed, now known only from Kansas and northern Eurasia (from England to western Siberia), being at the same time completely unknown from the northern Siberia, European Arctic, Canadian Arctic archipelago, and Canadian western interior. Thus, *B. praecursor* might, perhaps, have immigrated into the western interior sea of North America from the south via England and the Atlantic coast of the United States, just as was the case with *Belemnitella* ex. gr. *americana* (Morton) at a later epoch of the Upper Cretaceous.

In conclusion, the writer would express the hope that more specimens of *B. praecursor* Stolley s. l. will be collected in *Hesperornis* beds of Kansas in the future, which would further elucidate its stratigraphic range in North America and improve the existing correlation of the local Upper Cretaceous formations and groups with the international standard stages of Upper Cretaceous epoch. Also it would be very important to find out whether or not this stratigraphically useful species also occurs in other regions of the western interior of North America, on Atlantic or Gulf coasts, or perhaps on the Arctic slope of Canada and United States.

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TWO NEW SPECIES OF THE EQUID GENUS *NEOHIPPARION* FROM THE MIDDLE PLIOCENE, CHIHUAHUA, MEXICO

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ABSTRACT—Two new closely related species of the equid genus *Neohipparion*, *N. floresi*, n. sp., and *N. arellanoi*, n. sp., are described from the middle Pliocene near the villages Yepómera, Rincón de la Concha, and Matáchic, Chihuahua, Mexico. These species show their nearest relationships to *Nechipparion eurystyle* (Cope) from the Panhandle of Texas and Oklahoma and are more distantly related to *Neohipparion phosphorum* (Simpson) from the Alachua fauna in Florida. They are among the more progressive species of the genus. A large number of maxillary and mandibular cheekteeth series, isolated cheekteeth and metapodials are available.

INTRODUCTION

SEVERAL years ago the late Dr. Chester Stock of the California Institute of Technology initiated rather extensive explorations in the continental Cenozoic deposits in Mexico. Large collections, particularly of fossil mammalian materials, have been assembled. One of the productive areas investigated was in the middle Pliocene exposures in the Rio Papigóchic valley near the villages Yepómera, Rincón de la Concha and Matáchic, Chihuahua, Mexico. Descriptions of fossils from this area have been written by Wilson (1937; 1949), Drescher (1939), Furlong (1941), Miller (1944), Stock (1948) and Lance (1950). A stratigraphic report on the area is being prepared by Lloyd C. Pray.

This report is a description of two new species of horses and a comparison with other species in the genus *Neohipparion*. Comparison has been difficult and perhaps not well established because of inadequate materials available to me representing the species *Neohipparion eurystyle* (Cope) and *Neohipparion phosphorum* (Simpson). Nevertheless, the Chihuahua species are, morphologically, among the more progressive species in the genus. Evidence indicates that *N. floresi*, n. sp., the more advanced of the two closely related Chihuhua species, was found at the California Institute of Technology localities 275—Arroyo Huachin, 281—Matáchic, and 287—Arroyo de Calabasas. The other species, *N. arellanoi*, n. sp., was taken from localities 276—Arroyo de las Burras, 286—Arroyo de las Barrancas Blancas, and 289—Arroyo de los Poños It is interesting to note, however, that Pray's studies on the stratigraphy offer no basis for a time difference between the assemblages from these localities.

All specimen and locality numbers are from the California Institute of Technology. Professors Robert P. Sharp and Ian Campbell have generously made these materials available for description. Dr. Lloyd C. Pray and Mr. William Otto have kindly given me much valuable information from their field notes. The collections were made by local Mexicans under the direction of J. W. Patterson. The illustrations were made by David P. Willoughby and Owen J. Poe. I am grateful to Helen Watkins for her help on the stratistical data.

SYSTEMATIC DESCRIPTIONS

NEOHIPPARION FLORESI[1]

Stirton, n. sp.
Text-figs. 1–5, 6a-b

Holotype.—Right and left upper cheektooth series and right lower cheektooth series, P_2^2–M_3^3, moderately worn, CIT 3327.

Paratypes.—Left P^2–M^3, moderately worn, CIT 3328; crushed palate and left maxillary P^2–M^3 both sides, little worn CIT 3331; part of right maxillary P^3–M^3, well worn, CIT 5069; left P^4–M^3, well worn, CIT 5071; left upper molar, little worn. CIT 5079. Left DP^{2-4}, moderately worn, CIT 3332. Right P_2–M_3, moderately worn, CIT 3333; right P_2–M_3, moderately worn,

[1] Named for the late Dr. Theodoro Flores, Director del Instituto Geologico, Mexico, D. F.

Comparative Diagnoses

The relationships of *N. floresi*, n. sp., *N. arellanoi*, n. sp., and *N. eurystyle* (Cope) are so close that a tabular arrangment of their diagnostic characters may facilitate a comparison of the species.

N. floresi Stirton, n. sp.	*N. arellanoi* Stirton, n. sp.	*N. eurystyle* (Cope)
Cheekteeth relatively high crowned in relation to occlusal dimensions, an isolated M^2 (5079) measures approximately 82 mm. from base to tip of parastyle, and an M_2 (5080) 75.3 from base to tip of parastylid.	Cheekteeth seem to average about 5–10 mm. shorter than in *N. floresi*, although two fragmentary isolated teeth (5090) marked loc. 276 are as high crowned[3] as CIT 5079 from loc. 275.	Cheekteeth about 15 mm. shorter than in *N. floresi*.
Parastyle on P^2 curved posteriorly; anterior end of lingual border of prefossette on P^2 usually extends farther forward than anterolabial corner.	Parastyle on P^2 curved posteriorly; anterior end of lingual border of prefossette on P^2 not farther forward than anterolabial corner.	Parastyle on P^2 not curved posteriorly; anterior end of lingual border of prefossette on P^2 usually not farther forward than anterolabial corner.
Protocones with lingual border straight or slightly convex, anterior and posterior ends usually with slight labial direction in early stages of wear.	Protocones usually with markedly concave lingual borders, anterior and posterior ends usually without slight labial direction in early stages of wear.	Protocones with lingual borders straight or slightly convex, anterior and posterior ends usually with slight labial direction in early stages of wear.
Anterior end of protocone of M^3 bifurcate (fish-pattern) in approximately upper third of crown, character also present in two second molars (5081).	Anterior end of protocone of M^3 not bifurcate except in one tooth (5084).[4]	Anterior end of protocone not bifurcate.
Prefossette loop (Fig. 1) tends to extend much farther lingually than other parts of fossettes.	Prefossette loop tends not to extend beyond lingual borders of fossettes.	Prefossette loop usually does not extend beyond lingual border of fossettes.
Protocone with anterolabial spur on DP^{3-4}, with anterior end sometimes bifurcate (fish-shape) on DP^4, medium size, lingual border not straight.	Protocones on DP^{3-4} without anterolabial spur, anterior end not bifurcate on DP^4, medium size, lingual border usually sharply concave in early stages of wear.	Protocones on DP^{3-4} without anterolabial spurs, anterior end not bifurcate on DP^4, small size, lingual border usually straight.
Anterior and posterior edges of M_3 tend to be parallel throughout their length, tooth relatively short anteroposteriorly.	Anterior and posterior edges of M_3 with greater tendency to converge toward apex of tooth, tooth longer than in *N. floresi* anteroposteriorly.	Anterior and posterior edges of M_3 with greater tendency to converge toward apex of tooth, teeth both long and short anteroposteriorly.
Lingual fold in metaconid-metastylid groove in early stages of wear in lower premolars more frequent and better developed than in any other species (Fig. 4).	Lingual fold in metaconid-metastylid groove only faintly indicated in some premolars.	Lingual fold in metaconid-metastylid groove only faintly indicated in some premolars.

(*Continued on next page*)

[3] One of these teeth evidently belonged to the same individual as a tooth from loc. 275 (possibly the locality numbers were confused while assembling the materials in the field). (See footnote 9.)

[4] This could have been mixed in assembling the specimens from the field or it could mark the inception of this character in populations older than those typified by *N. floresi*.

N. floresi Stirton, n. sp.	*N. arellanoi* Stirton, n. sp.	*N. eurystyle* (Cope)
Metaconid and metastylid not conspicuously flattened with resultant shallowing of metaconid-metastylid groove especially in later stages of wear in premolars.	Metaconid and metastylid not conspicuously flattened with resultant shallowing of metaconid-metastylid groove especially in later stages of wear in premolars.	Metaconid and metastylid conspicuously flattened with resultant shallowing of metaconid-metastylid groove especially in later stages of wear in premolars.
Narrow spur on paralophid of DP_2 closes or nearly closes metaflexid; metaflexid sometimes with faint enamel inflection.	Narrow spur on paralophid of DP_2 closes or nearly closes metaflexid; metaflexid sometimes with faint enamel inflection.	No narrow spur on posterior surface of paralophid, metaflexid widely open; metaflexid without faint enamel inflection.
Lingual enamel fold clearly indicated or absent in metaconid-metastylid groove on DP_{2-4} in early stages of wear.	Not known.	Lingual enamel fold usually absent but sometimes faintly indicated in metaconid-metastylid groove on DP_{2-4} in early stages of wear.

CIT 3334; left P_2–M_3, moderately worn, CIT 3335; left P_2–M_2, M_3 broken, moderately worn, CIT 3336; left P_2–M_3, well worn, CIT 3337; part of left mandible P_2-M_2, well worn, CIT 5075; right P_2–M_3 with M_1 broken, well worn, CIT 5076; right P_2–M_2, moderately worn, CIT 5077; left P_3–M_3, well worn, CIT 5078; right M_{1-3}, little worn, CIT 5080. Isolated cheekteeth: P^3–M^2, one hundred and eighteen; P^2, eight; M^3, thirty-six; P_3–M_3 thirty-seven DP^{2-4}, six; DP_{2-4} fourteen. Metacarpals III, seven. Metatarsals III, five.

Referred specimens.—Matáchic—loc. 281. Part of left maxillary P^2–M^3, CIT 3329; right mandibular fragment P_2–M_3, moderately worn, CIT 3338; part of right mandible P_2–M_2, moderately worn, CIT 3339. Metacarpals III, three. Metatarsals III, one.

Arroyo de Calabasas—loc. 287. Pair of mandibles with symphysis, left P_2–M_3 with M_3 broken, right P_2–M_2, well worn, CIT 5073; right DP_{2-4}, little worn, CIT 3505.

Type locality.—Gray-green and maroon interbedded clays, tuffs, and silts; Arroyo Huachin, Rio Papigóchic valley, near pueblo Rincón de la Concha, 150 kilometers west of Chihuahua, Mexico. CIT–275.

NEOHIPPARION ARELLANOI[2] Stirton, n.sp.
Text-figs. 6 C–H, 7

Holotype.—Part of right mandible P_2–M_3, little worn, CIT 5074.

[2] Named for A. R. V. Arellano, stratigrapher, Instituto Geologico, Mexico, D. F.

Paratype: Crushed left maxillary P^2–M^2 P^2 broken and fragments lost since it was illustrated, well worn, CIT 3330; part of right maxillary P^4–M^3, well worn, CIT 5068; part of right maxillary P^4–M^2, half of P^4 and M^2 broken away, well worn, CIT 5070. Pair of mandibles without symphysis P_2–M_3, well worn, CIT 5072; left P_4–M_3 little worn, CIT 5082; part of left mandible P_4–M_3, well worn, CIT 5085; part of right mandible P_2–M_3, well worn, CIT 5086; part of right mandible P_4–M_3, well worn, CIT 5087; part of right mandible with symphysis P_3–M_3, heavily worn, CIT 5088. Isolated permanent upper cheekteeth, thirteen; isolated upper milkteeth, five. Metacarpals III, two. Metatarsals III, two.

Referred specimens.—Arroyo de los Poños—loc. 289. Part of left maxillary M^{2-3}, well worn, CIT 3083; left M^3, little worn, CIT 5084; part of left mandible P_3–M_2, well worn, CIT 5089. Isolated cheekteeth: P^2–M^2, thirty-eight; M^3, ten; P^2 three; P_2–M_2, six; M_3, four; P^2, one; DP^2 two. Metacarpals III, four. Metatarsals III, two.

Arroyo de las Barrancas Blancas—loc. 286. Isolated cheekteeth: P^2–M^2, six; M^3, two; P_2–M_2, nine; P_2, one; M_3, three.

Type locality.—White and gray tuffs and clays interbedded with limestone and capped by a 2-foot limestone member, Arroyo de las Burras about 3 kilometers east of Arroyo Huachin and approximately 4 kilometers north of Yepómera, 150 kilometers west of Chihuahua, Mexico. CIT–276.

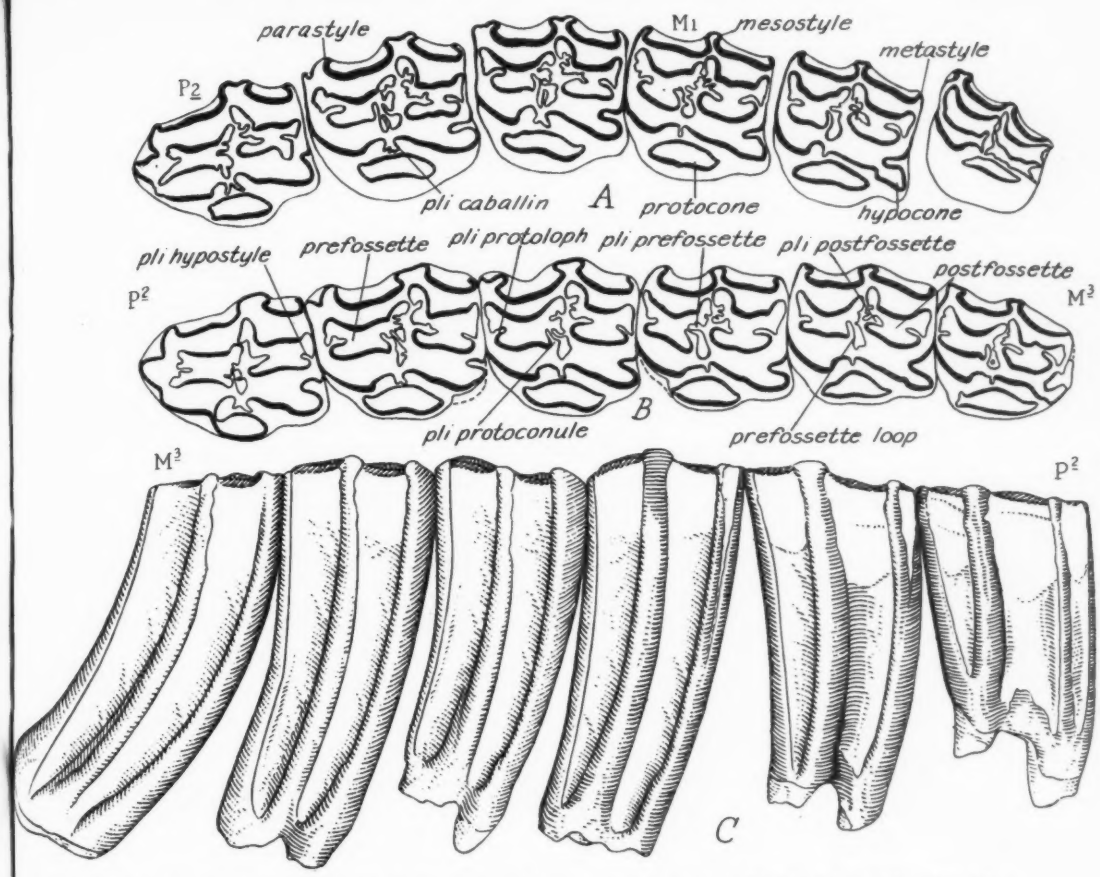


FIG. 1—*Neohipparion floresi* Stirton, n. sp., natural size. A. Occlusal view P^2–M^3; Matáchic—loc. 281; CIT 3329. B C. Holotype, occlusal and labial views P^2–M^3; Arroyo Huachin—loc. 275; CIT 3327.

Descriptive Details

The description included here is intended to help the reader also in checking characters not diagnostic in *N. floresi*, n. sp., and *N. arellanoi*, n. sp., which he may find useful in comparison with other groups in the genus. Some of the diagnostic characters of the species are not duplicated here.

Upper permanent cheekteeth: Parastyles with tendency to curve posteriorly on P^2, strongly curved posteriorly on other teeth, usually grooved in upper part of tooth on premolars rounded on molars. Mesostyles flattened and usually grooved on premolars, rounded not flattened or grooved on molars. Metastyles much smaller than the other stylar cusps but distinct, with anterior curvature. Fossettes narrow and elongate but in later stages of wear less elongate; pli protoloph usually present but sometimes absent particularly in later stages of wear and sometimes with one or two additional tiny plications on anterior border of prefossette especially on P^2; pli protoconule with transverse or anterolabial direction in P^3 and P^4; two to five small plications including pli prefossette on posterior border of prefossette particularly in early stages of wear, and some of these plications may be secondarily divided; anterolabial wing of postfossette developed as high arched loop on P^3 and P^4; *prefossette loop*[5] (Fig. 1)

[5] New term for posterior lingual lobe of prefossette, immediately posterior to and mostly formed by pli protoconule. Cope (1886, p. 360) called this the subquadrate central loop.

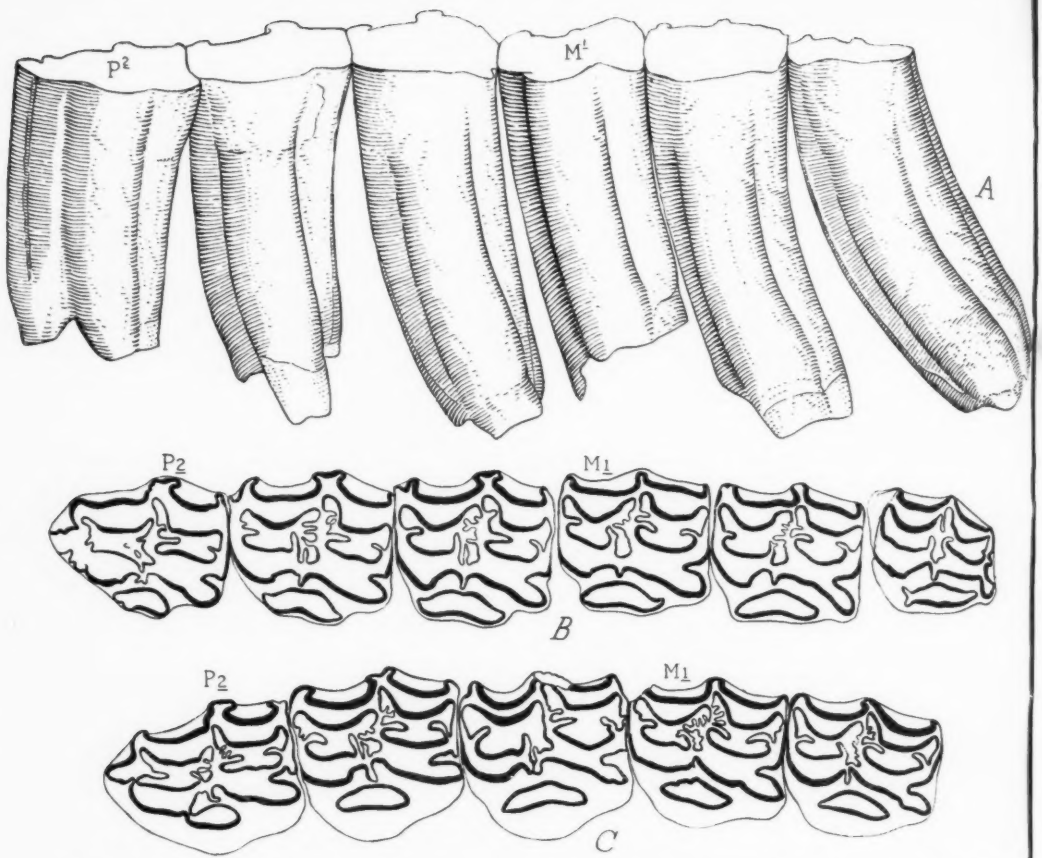


FIG. 2—*Neohipparion floresi* Stirton, n. sp., natural size. A. Holotype, lingual view P^2–M^3; Arroyo Huachin—loc. 275; CIT 3327. B. Occlusal view P^2–M^3; Arroyo Huachin—loc. 275; CIT 3328. C. Occlusal view P^2–M^3; Arroyo Huachin—loc. 275; CIT 3331.

usually bifid in P^3 and P^4, except in holotype, and single in molars; two to three plications on anterior border of postfossette including pli postfossette, sometimes these are secondarily divided into smaller plications; pli hypostyle only plication on posterior border of postfossette. Hypoconal groove open to base of tooth. Pli caballin single in molars but sometimes with two or three plications in premolars, not greatly enlarged. Protocone elongate, maximum elongation on P^3, P^4 and M^3, more closely appressed to central body of tooth in P^2, M^{1-3}, less so in P^3 and P^4, shorter on P^2 than in other teeth of series, narrow, lingual edge slightly concave or nearly straight, labial edge convex, connected to protoselene in four of seven specimens in P^2, isolated in all other teeth. Anterior edge of teeth straight or nearly so in premolars, strongly convex except in earliest stages of wear on molars. When M^3 becomes slightly worn the height of crowns from highest to lowest are in the order: M^3, M^2, P^4, M^1, P^3, P^2.

Upper deciduous cheekteeth: Teeth nearly rectangular in outline, slightly more than half as wide as long. Parastyles grooved and curved posteriorly. Mesostyles grooved, project both anteriorly and posteriorly on DP^2 and DP^3, directly anteriorly in DP^4. Parastyles and mesostyles become progressively smaller from DP^2 to DP^4. Metastyles well developed but not grooved, progressively more widely separated from mesostyle from DP^2 to DP^4. Styles with minimum labial expansion. Fossettes on DP^2–DP^4

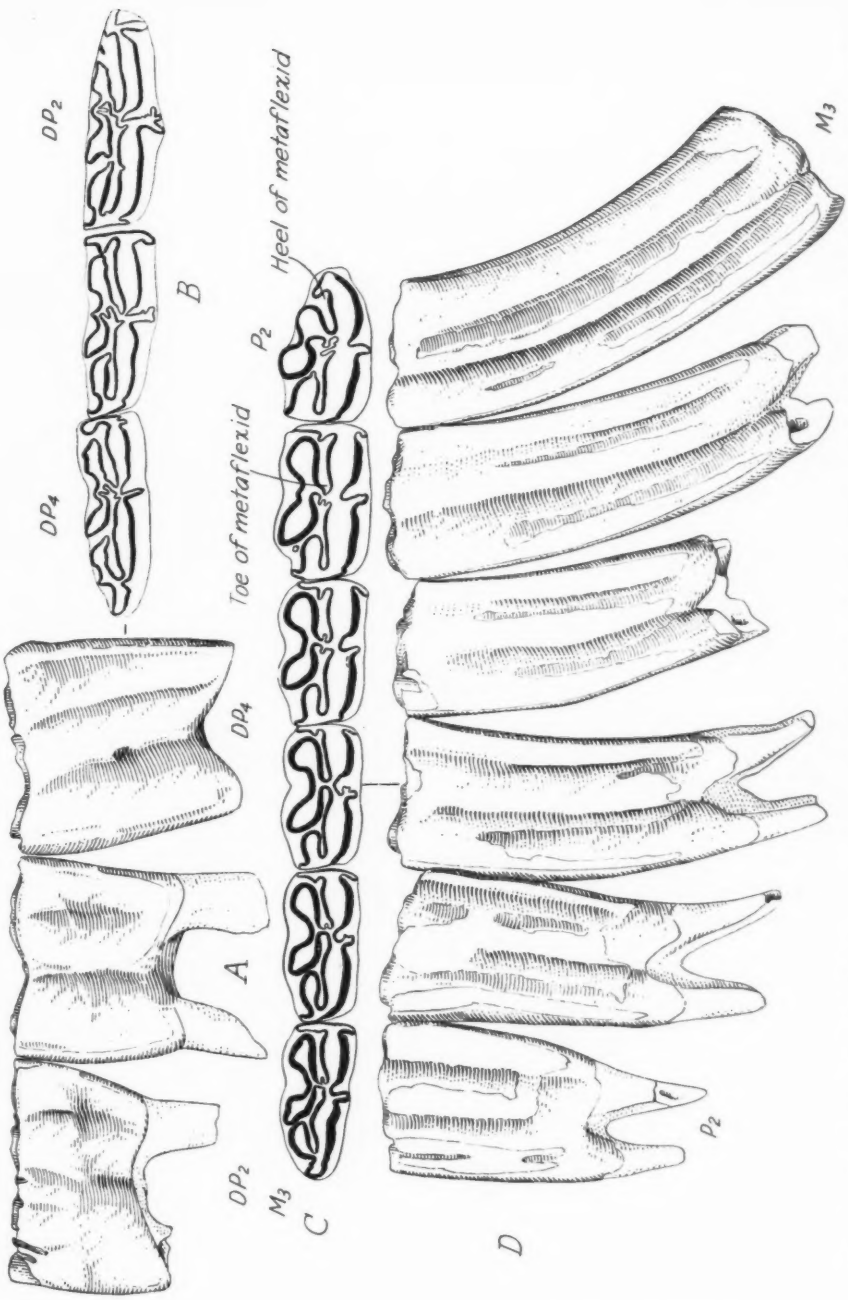


FIG. 3—*Neohipparion floresi* Stirton, n. sp., natural size. A–B. Labial and occlusal views DP_2–DP_4; Matáchic—loc. 281; CIT 3505. C–D. Holotype, occlusal and labial views P_2–M_3; Arroyo Huachin—loc. 275; CIT 3327.

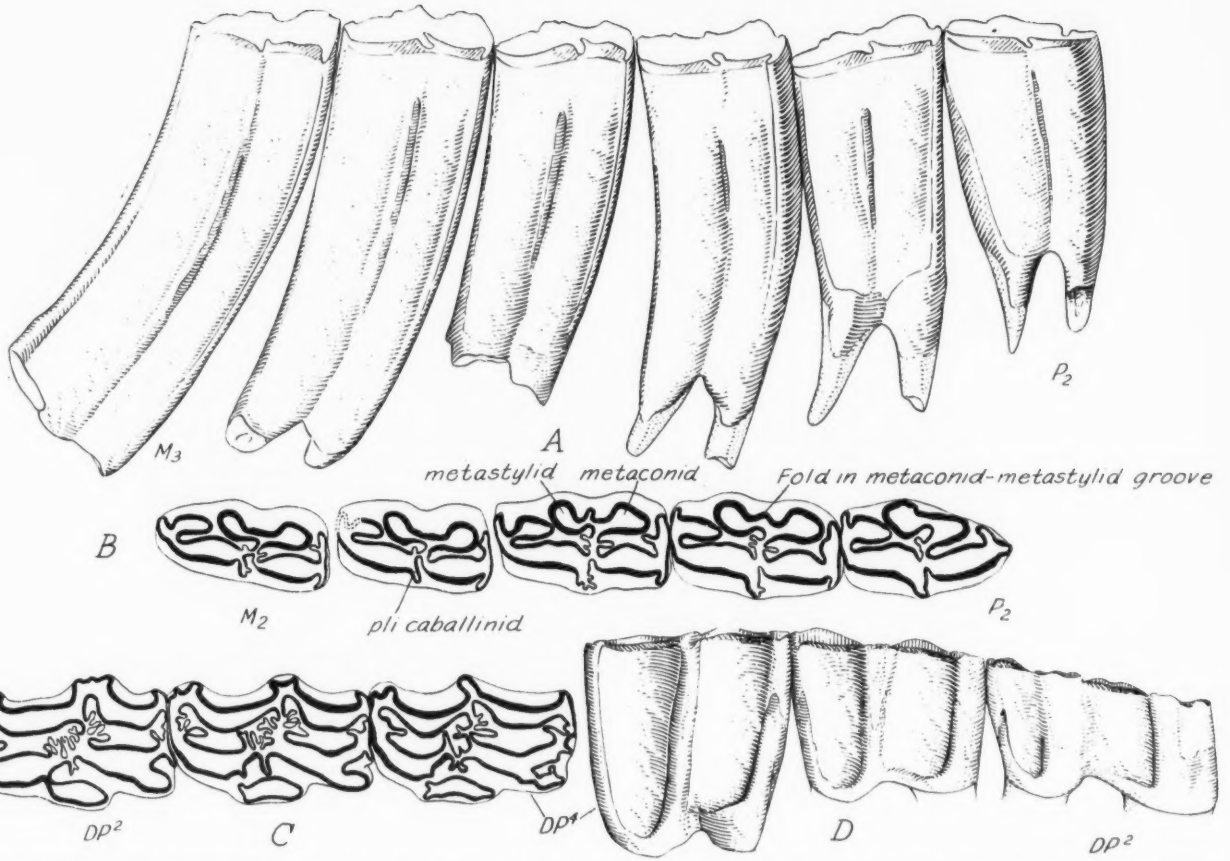


FIG. 4—*Neohipparion floresi* Stirton, n. sp., natural size. A. Holotype, labial view P_2–M_3; Arroyo Huachin—loc. 275; CIT 3327. B. Occlusal view P_2–M_2; Matáchic—loc. 281; CIT 3339. C–D. Occlusal and labial views DP^2–DP^4; Arroyo Huachin—loc. 275; CIT 3332.

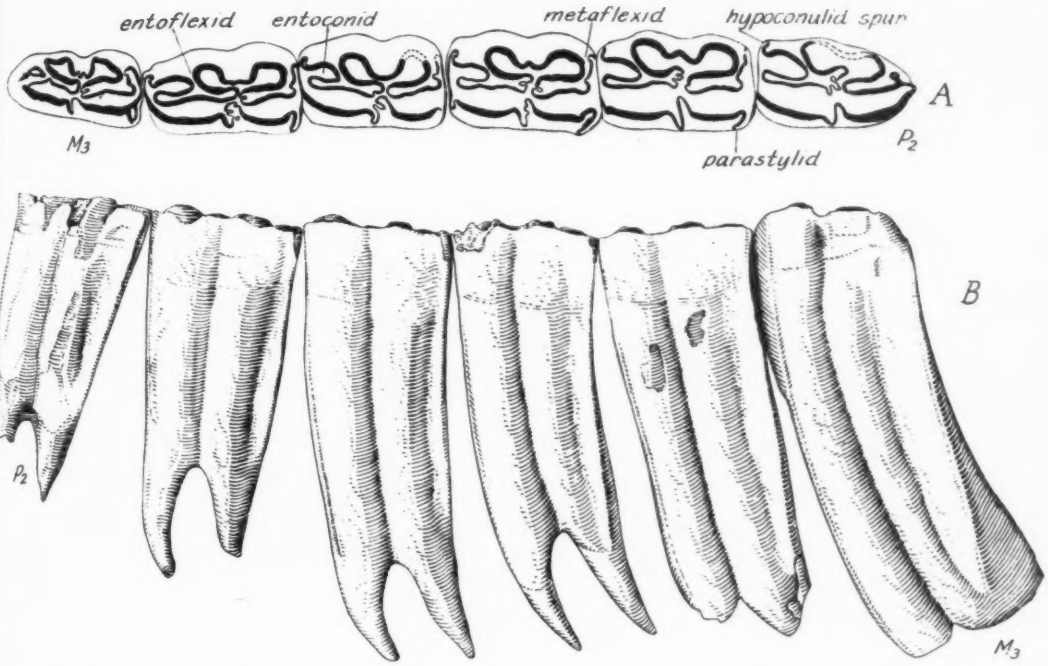


FIG. 5—*Neohipparion floresi* Stirton, n. sp., natural size. A–B. Occlusal and lingual views P_2–M_3; Matáchic—loc. 281; CIT 3338.

greatly elongate and narrow; isolated small fossette at anterior end of DP^2; three or less plications on anterior border of prefossette including pli protoloph; eight plications on posterior borders of prefossettes including small pli protoconules and pli prefossettes; prefossette loops not enlarged; four plications on anterior border of postfossettes including pli postfossettes; two plications on posterior border of postfossettes including pli hypostyles.

Fossettes on DP^4: fossettes much simpler in construction than on DP^2 and DP^3; greatly elongate and narrow; pli protoloph and faint indication of another plication on anterior border of prefossette; pli protoconule deeply invaginated into prefossette, three additional tiny plications on posterior border of prefossette including pli prefossette; prefossette lobe well developed, with slight bifurcation; three plications on anterior border of postfossette including pli postfossette; pli hypostyle and indication of another tiny plication on posterior border of postfossette. Hypoconal groove open to base of tooth, more complex borders on DP^4. Pli caballin single on DP^3, double on DP^2 and DP^4. Protocone elongate, narrow, posterior ends tend to be pointed, convex labially, concave lingually, connected to protoselene on DP^2, anterior bifurcation on DP^4 with spurs on adjacent areas of protoselenes. Become progressively higher crowned from DP^2 to DP^4.

Lower permanent cheekteeth: Last two premolars and first two molars nearly rectangular in outline. Anterior end of paralophid on or near midline of P_2; narrow spur near tip of paralophid on P_2 with posterior lingual direction, makes narrow constriction of mouth of metaflexid, connected to metaconid in one specimen (CIT 3336), not present on other cheekteeth. Metaflexid with short rounded anterior heel and long narrow posteriorly directed toe on P_2 and on molars, in some well worn P_2's and in other premolars toe of metaflexid parallel to anteroposterior axis of tooth; toe and heel of metaflexid each with enamel inflection usually present on all cheekteeth except P_2, particularly in early stages of wear. Metaconid and metastylid separated

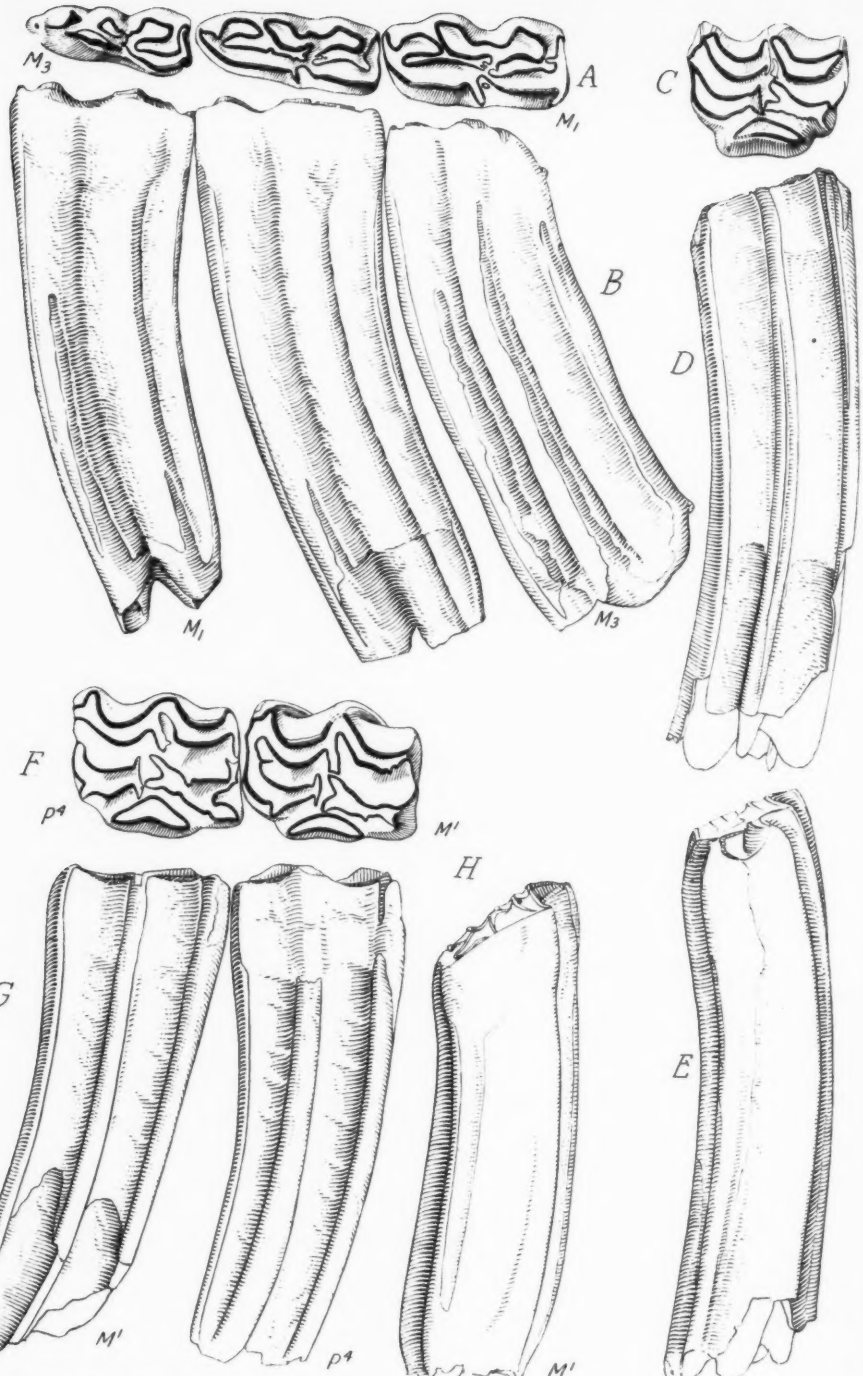


FIG. 6—All figures natural size. A–B. *Neohipparion floresi* Stirton, n. sp., occlusal and lingual views M_1–M_3: Arroyo Huachin—loc. 275; CIT 5080. C–D. *Neohipparion floresi* Stirton, n. sp., occlusal, labial and posterior views of upper molar; Arroyo Huachin—loc. 275; CIT 5079. F–H. *Neohipparion arellanoi* Stirton, n. sp., occlusal, labial and posterior views P^4–M^1; Arroyo de las Burras—loc. 276; CIT 5082.

by wide U-shaped groove to base of tooth in all teeth except in some specimens of P_2 where it is narrower; lingual enamel fold slightly or well developed in metaconid-metastylid groove on P_3 and P_4 in about two of every three specimens, seldom present in other teeth. Entrance of entoflexid tightly compressed between metastylid and entoconid; entoflexid in early stages of wear usually with one or two plications at anterior end or on anterior labial border. Entoconid usually without anterior spur, semilenticular, decreases in size from P_2 to M_3 much smaller than metastylid especially on P_4 to M_3, adjacent to labial half of metastylid. Hypoconulid spur (Fig. 5) well developed but not prominent, slightly curved anteriorly. Labial enamel borders of protoconid and hypoconid flattened except opposite protoconic of P_2, Parastylid[6] (Fig. 5) prominent, strongly curved posteriorly, not present on P_2. Pli caballinid single, prominent, extends as far lingually as parastylid in early stages of wear but not in later stages of wear. Hypoconulid of M_3 small, not much expanded or enlarged toward base of tooth. M_3 only slightly longer anteroposteriorly than other cheekteeth except in late stages of wear. When M_3 becomes slightly worn the height of crowns from highest to lowest are in the order: M_3, M_2, P_4, M_1, P_3, P_2.

Deciduous lower dentition: Narrow spur on paralophids of DP_2 and DP_3 closes or nearly closes metaflexid, sometimes absent on DP_4. Metaflexid much as in permanent teeth but longer and narrower sometimes with enamel inflection. Metaconid and metastylid separated by wide shallow U-shaped groove to base of tooth; lingual enamel fold faintly indicated in three of 13 specimens in metaconid-metastylid groove. Entrance of entoflexid 1.0 mm. or less in width; entoflexid with one or no plications at anterior end in early stages of wear, constricted laterally and much more elongate than in permanent teeth. Entoconid narrow, elongate, pointed anteriorly, extends nearly as far lingually as metastylid. Hypoconulid spur prominent. Labial borders of protoconid and hypoconid flattened. Parastylid as in permanent teeth. Pli caballenid single on DP_4 but larger and with as many as three plications at its labial end on DP_2. Slight increase in height of crown from DP_2–DP_4.

The two metatarsals of *N. eurystyle* from Texas are slightly shorter (212 and 234 mm.) than any of *N. floresi* or *N. arellanoi*, which are closely grouped in their total length measurements (*N. floresi*, six specimens, mean length 236 mm.; *N. arellanoi*, four specimens, mean length 240 mm.).

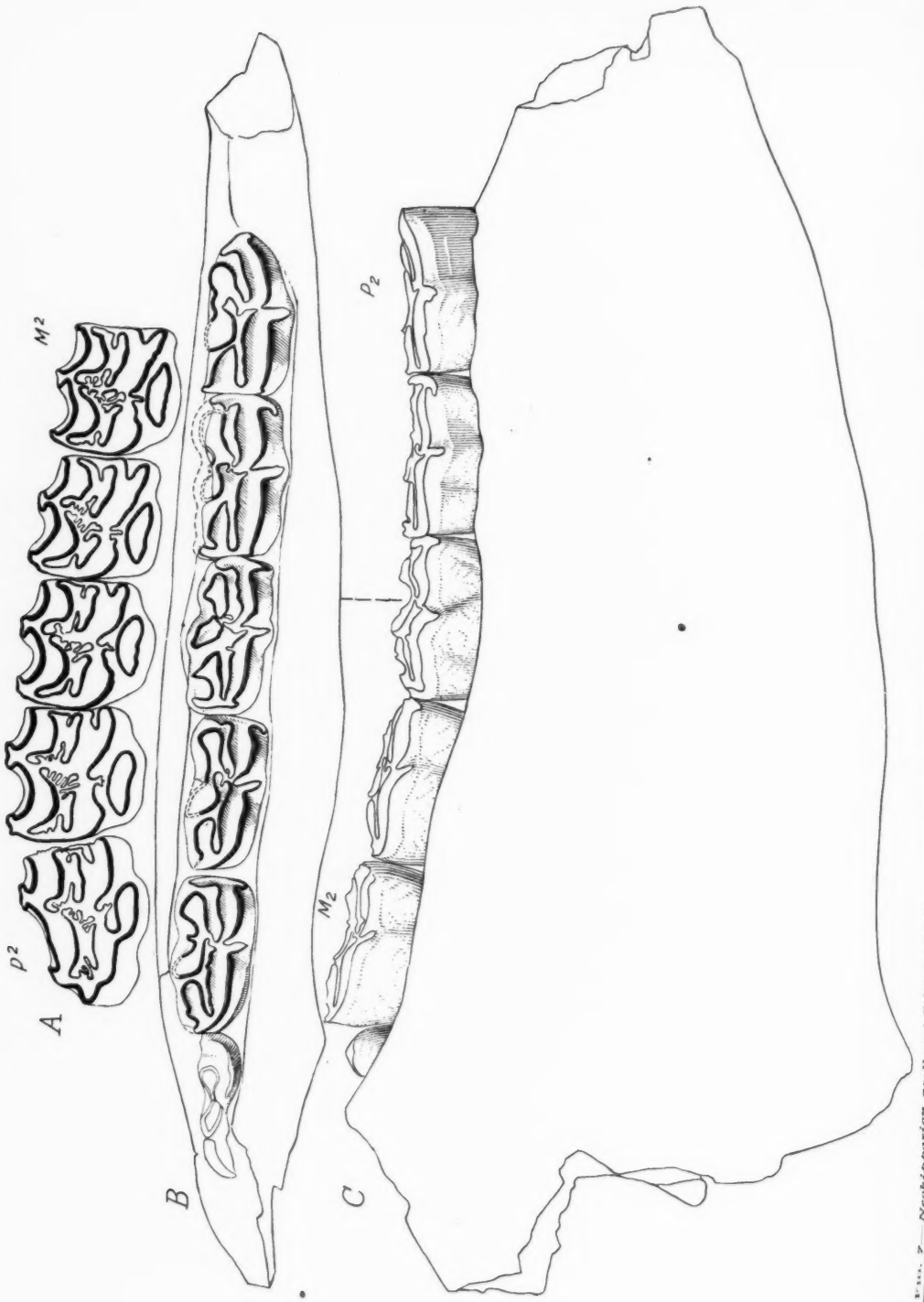
Discussion.—The possibility of two closely related yet synchronic species of horses occurring in the area of the Papigóchic valley in the Hemphillian provincial age seems doubtful. Examples of closely related species of grazing mammals of this size occupying the same environment, or in closely adjacent ecologic niches is not common. Synchronic species as widely separated as Florida and Chihuahua are not infrequent. In any event the evidence here indicates that the two forms from Chihuahua came from different local localities.

Differences of the magnitude displayed in the two Papigóchic species could be readily understood as allochronic speciation. But, in Lloyd C. Pray's study of the stratigraphy he

> . . . can see no valid stratigraphic differentiation between localities 275, 281, and 287 on the one hand, and localities 276, 286, and 289 on the other. The stratigraphic range represented by 275, 281, and 287 includes beds older and younger than 276, 286, and 289. Furthermore, I can see no valid basis for an environmental differentiation as both groups of localities involve similar lithologic facies. (Written communication, Sept. 24, 1952.)

In the Great Plains region and elsewhere the evidence of superposition in continental beds is at times difficult to determine because of the intermittent deposition and channeling effects of stream deposits. Frequently, under these conditions fossils are washed out and redeposited with the remains of animals of a later age, but these usually can be detected readily because of their small number or by the effect of abrasion on them, and hence, are seldom con-

[6] This use of parastylid is different from that of Osborn (1918, p. 4, fig. 1) where he seems to indicate a spot in the middle of the paralophid, which cannot be a stylid. Current usage refers to the crest on the anterolabial corner as the parastylid.


M2
P2
A
B
P2
M2
C

confusing in a correlation of the beds. Sometimes a few feet of down cutting over a wide alluvial plain can be quite confusing in determining the superposition of beds. In areas like this the overlying later deposits and the soil mantle make it almost impossible to trace the members from one exposure to another. This becomes particularly confusing when the lithology is the same in an area where volcanic materials have come from different local sources at slightly different times, or where the same materials have been reworked and secondarily deposited. This is well demonstrated in the San Francisco Bay region where we have had to use the evidence from fossil mammals to date the stratigraphic units in which they occur. These are mentioned only as a possible solution to the problem in the Papigóchic valley.

It is also possible, even though the samples before us are relatively large, that the differences seen are variations in a local population and that further collecting would clarify this situation. Therefore, an analysis of the diagnostic characters of the two proposed species may give a clearer understanding of their validity.

Discussion of Diagnostic Characters

The height of crown in the cheekteeth is difficult to determine in hypsodont equids except in a few specimens even in relatively large samples. If the tooth is not worn, or sometimes when it is little worn, the base of the crown is not formed or is broken. If the base is well formed, the tooth is usually worn to a pcint where its total crown height is no longer determinable. In closely related species like these a slight difference in the standard range could be significant if accurate measurements of a series could be made.[7] Though there is viaration in the crown height in different individuals, *N. arellanoi*, n. sp., seems to average from 5–10 mm. lower crowned than *N. floresi*, n. sp.[8]. This character is only suggestive.

[7] This does not suggest that stage or age correlation based on hypsodonty is invalid. The studies here are of much greater refinement.

[8] The two teeth, CIT 5090—loc. 276 and CIT 5079—loc. 275, seem rather clearly to have come from the same animal. They are evidently M^1 or M^2 but from opposite sides of the maxillary. They match almost exactly in every feature available for observation (one tooth is broken). Thus there may be some mixture in the field data.

The anterior end of the lingual border of the prefossette on P^2 extends farther forward than the anterolabial corner in nine of twelve specimens of *N. floresi* from localities 275 and 281. In the only three specimens of *N. arellanoi* from locality 276 the inner border is not farther than the anterolabial corner. Though the sample is small for both species the differences seem significant.

The inner edges of the protocones tend to be straighter in *N. floresi*, where as in *N. arellanoi* they tend to be markedly concave. This feature is perhaps more variable than any listed in the diagnosis. Frequently, it varies in different stages of wear and is difficult to evaluate.

The bifurcation of the anterior end of the protocone (fish-pattern) in the early stages of wear in M^3 is one of the most consistent characters. It is seldom if ever present when the tooth first starts to wear nor is it present in the lower half of the crown. It is present in 17 specimens or all of the specimens of *N. floresi* in early stages of wear from locality 275, and it is even present in two of the first or second molars no. 5081. Of the seven specimens of *N. arellanoi* from localities 276 and 289 one has the fish-tail pattern and it is absent in the others. This could mark one of the first appearances of the character in a less progressive population or it could have been mixed in applying the field number as is indicated in another instance.

The lingual extension of the prefossette loop (Fig. 1, B) though variable in its length seems significant in the sample of *N. floresi* from locality 275, where 70 of 82 specimens show an extension beyond the lingual borders of the fossettes. On the other hand the sample of *N. arellanoi* from locality 289, though with the prefossette loop less extensive lingually, shows 11 of 27 individuals that project at least beyond the borders of the fossettes. The smaller sample of *N. arellanoi* from locality 276 is even more distinct from *N. floresi* in that only two out of eleven show a slight extension beyond the fossette borders.

The deciduous molars (DP^{3-4}) of *N. floresi* show an anterolabial spur on the protocone in all of the five specimens in early stages of wear, and the fish-tail pattern is developed on one. All of these are from locality 275. The three specimens of *N. arel-*

STATISTICAL DATA

Anteroposterior measurement of upper molars

	N	OR	SR	M	σ	V
N. floresi, n. sp.	24	19.1–21.5	3.37	20.0± .11	.52± .8	2.6 ± .38
N. arellanoi, n. sp.	11	18.2–21.0	4.86	19.6± .23	.75± .16	3.83± .82
N. eurystyle	7	18.7–20.7	4.67	19.5± .27	.72± .19	3.69± .99
Transverse diameter of upper molars across mesostyle and posterior end of protocone 40 mm. above base of tooth						
N. floresi	24	17.3–19.8	3.37	18.5± .11	.52± .08	2.81± .41
N. arellanoi	11	17.3–20.7	6.6	18.5± .31	1.03± .22	5.57±1.19
N. eurystyle	7	17.4–19.9	6.22	18.2± .36	.96± .26	5.27±1.41
Anteroposterior length of protocone 40 mm. above base of tooth						
N. floresi	24	8.7–11.4	4.73	10.1± .15	.73± .11	7.23±1.04
N. arellanoi	11	8.3–10.0	3.69	9.1±1.7	.57± .12	6.26±1.33
N. eurystyle	7	7.6–10.5	5.90	8.8± .34	.91± .24	10.34±2.77

N = number of specimens
OR = observed range.
SR = standard range.
M = mean and its standard error.
σ = standard deviation and its standard error.
V = coefficient of variation and its standard error.

lanoi from locality 276, two in early stages of wear, show no spur and the protocone is sharply crescentic in outline, in contrast to a nearly straight lingual border in *N. floresi*.

The lower molars, M_3, in *N. floresi* are consistently shorter anteroposteriorly and show less tendency to converge toward the top of the crown. In these teeth *N. arellanoi* seems to be larger and shorter crowned. The mean averages of the samples of *N. arellanoi* (24.5 mm.) are more than 3 mm. longer anteroposteriorly 20 mm.± above the base of the teeth than in *N. floresi* (21.7 mm.) and there is no overlap in the measurements in the samples available, though I expect a larger sample might show a slight overlap.

The lingual fold in the metaconid-metastylid groove in the lower premolars is a conspicuous character, and though it is variable in its intensity in *N. floresi* it is much more prominent than in *N. arellanoi* where it is absent or faintly indicated in early stages of wear. I have not been able to derive a quantative value for this character though it is very useful as a qualitative feature.

Remarks.—There are nine diagnostic characters in the cheekteeth of *N. floresi*, n. sp., and *N. arellanoi*, n. sp., that demonstrate the validity of the two species. A survey of all of the features in the teeth and in the metapodials indicate a remarkably close relationship. It is felt, however, that the differences are of greater magnitude than in adjacent subspecies of Recent faunas. Since there is an intergradation in some but not in all of the characters, these forms may represent part of a subspecies chronocline but there is no stratigraphic control to support that contention.

Comparisons

Neohipparion floresi, n. sp., and *N. arellanoi*, n. sp., are closely related to *N. eurystyle* (Cope), 1893, from the Goodnight, Hemphill and Optima faunal assemblages in the Panhandles of Texas and Oklahoma. *N. eurystyle* was originally based on three permanent lower teeth from the edge of Palo Duro Canyon on the Goodnight ranch. Though these may belong to a slightly more advanced species than the specimens from Hemphill and Optima, the populations as

represented by these Panhandle samples are very closely related if not conspecific. This is demonstrated in the conspicuously flattened metaconids and metastylids in the premolars with a resultant shallowing of the metaconid-metastylid groove. Nevertheless, it is difficult to make satisfactory comparisons with *N. eurystyle* because of the paucity of materials from Texas and Oklahoma for study.

The most significant difference between *N. eurystyle* and the Mexican species may be found in the diagnosis. Some of these features are less distinctive than others. For example, the bifurcate anterior end of the protocone (fish-pattern) on M^3 and the depth of the metaconid-metastylid groove on the premolars are much more consistent than the lingual extension of the prefossette loop or the anterior extension of the inner border of the prefossette on P^2. On the whole *N. eurystyle* is more closely related to *N. arellanoi* than it is to *N. floresi*. On the other hand *N. arellanoi* resembles *N. floresi* more than it does *N. eurystyle* except in height of crown in the cheekteeth. The sizes of the individuals in the populations are very much alike. There are some large limb and foot bones from Arroyo de las Barrancas Blancas —loc. 286 that may belong to a larger species than those described here and some of the teeth may be referable to animals with limb bones like these, but an association of body skeletal parts and teeth as referable to individual animals cannot be made with these materials.

The type and only tooth of *N. phosphorum* (Simpson), 1930, from the Alachua fauna in Florida differs in its larger size, though any single measurement can be matched in the Texas or Mexico specimens. Nevertheless, *N. phosphorum* would seem to average consistently larger. The tooth is too much worn to determine the height of crown in the species. Anteroposterior length 21.4 mm.; transverse across mesostyle 19.7; length of protocone 11.6 (measurements taken 40 mm. above base of tooth).

N. rectidens (Cope) from Tehuichila, Mexico, evidently is another species related to *N. floresi* and *N. arellanoi*. The following differences in the type specimen which has been called a premolar have been noted. Parastyle not curved posteriorly and mesostyle not curved anteriorly; parastyle and mesostyle not grooved or flattened; anterolabial wing of prefossette not developed as a high arched loop; fossettes wider and less elongate; prefossette loop with abnormal connection to postfossette; two large pli caballins; deep hypoconal groove.

N. sinclairi (Wortman), *N. molle* Merriam, *N. leptode* Merriam, and *N. gidleyi* Merriam from western United States, though broadly referable to the *N. eurystyle* group of neohipparions, are more distantly related to *N. floresi* and *N. arellanoi* than the Hemphillian species from Texas, Florida and Mexico. They show numerous differences. Larger but shorter crowned cheekteeth (height of crown in *N. gidleyi* when unworn teeth are found may be equivalent). Upper teeth: parastyles not strongly curved posteriorly nor metastyles strongly curved anteriorly particularly on molars; mesostyles not flattened nor grooved on premolars; fossettes not so narrow and elongate; anterolabial wing of postfossette more angulate than loop-like in premolars; prefossette loop not as large nor as elongate, does not extend lingually beyond inner edge of fossette; posterior end of protocone without labial direction in P^3 and P^4; no tendency for bifurcation of anterior end of protocone on M^3; anterior edge of M^1 and M^2 only slightly convex. Lower teeth: anterior end of paralophid slightly linguad of midline on P_2; mouth of metaflexid not narrowly constricted by spur from paralophid on P_3; no lingual enamel fold in metaconid-metastylid groove on premolars; entrance of entoflexid not tightly compressed by entoconid and metastylid except in premolars where a spur occurs on anterior end of entoconid (in *N. sinclairi* it seems to be tightly compressed as in *N. floresi*); entoconid with spur on anterior end in premolars; labial enamel borders of protoconid and hypoconid not as flattened; hypoconulid more enlarged and expanded toward base of tooth; M_3 conspicuously more elongate anteroposteriorly than other cheekteeth.

N. floresi would not be confused with Clarendonian species like *N. coloradense* Osborn and *N. occidentale* (Leidy), as shown by Stirton (1953).

MEASUREMENTS IN MILLIMETERS

	Neohipparion floresi							N. arellanoi		
	3327*	3327*	3328	3329	3331	5069	5071	3330	5068	5070
PERMANENT UPPER TEETH										
Length across occlusal surfaces										
P^2–M^3	119.6	121.0								
P^2–M^2	102.2	103.0			114.9					
P^2–P^4	64.0	64.8			71.7					
P^4–M^3	76.3	76.8			89.4					
P^3–M^2	79.3	80.3								
Width across mesostyle and posterior end of protocone										
P^3	19.3	19.0	20.0	19.3	20.0					
M^2	17.5	17.0	17.7	17.5	17.8					
Length and width of protocone										
P^2	6.8×3.7	7.1×3.5	7.9×3.7	8.3×3.7	7.6×4.0					
P^3	10.2×3.4	10.1×3.9	11.2×3.5	10.2×3.4	10.1×4.0	11.9				
P^4	10.1×3.2	10.5×3.5	11.9×3.2	10.9×3.4	11.7×4.1	10.8×3.5	9.9×3.8		9.2×4.2	
M^1	9.6×3.5	9.2×3.5	10.5×3.3	10.0×3.5	9.8×3.9	10.0×4.0	8.7×3.7		10.2×3.7	8.2×3.5
M^2	9.3×3.2	9.3×3.4	10.6×3.1	10.5×3.4	9.3×3.5	9.9×4.0	8.9		9.0×3.5	
M^3	10.5×3.2	11.0×3.0	11.5×3.5	9.3×2.9		10.3×3.0	8.7×3.2		9.9×3.0	
Anteroposterior length at crown and at base—parastyle to metastyle										
P^4	20.2×15.5	20.8×15.4	21.1×16.8							
M^2	19.3×16.1	19.4×16.7	20.0×16.5							
M^3	18.3×21.5	18.5×21.5	18.3×22.0							
Crown height from base of enamel to tip of parastyle										
P^4	50.5	51.3	58.3							
M^2	51.9	53.5	62.0							
M^3	57.6	55.5	59.5							

* Where the same specimen number is used in two columns, it refers to the right and left sides of the same individual.

	Neohipparion floresi									N. arellanoi		
	3334	3335	3336	3337	3338	3339	5073	5075	5076	5077	5078	5072	5074
PERMANENT LOWER TEETH													
Length across occlusal surfaces													
P_2–M_3	116.5			120.0								120.4† 120.5	
P_2–M_2	97.5		110.5	110.3		111.5	111.1 104.1	90.2		104.3		98.2 99.2	115.5
P_2–P_4	58.6		62.8	61.5		69.7	61.7 63.0	71.7		62.8		59.0 59.5	70.0
P_4–M_3	76.7		80.1	80.0				54.3			113.5	81.7 82.0	
P_2–M_3	77.9			79.5		89.0	79.2 83.0	71.8		84.2	80.6	78.6 79.3	92.4
Width across metaconid-protoconid													
P_2	9.1	10.0	9.7	9.2		9.3	9.4 9.4	10.5	9.4	10.5		10.3 10.0	8.8
P_3	10.1	11.8	11.1	11.1		10.9	12.1 12.1		11.6	11.2	11.2	11.1 11.6	
P_4	10.1	11.0	10.7	11.1		10.3	11.8 12.0	11.4	10.8	10.9	11.2	12.3 12.2	8.2
M_1	8.7	9.9	10.0	9.4		9.3	9.9 10.6	11.3	9.8	9.5	9.8	10.9 10.9	88.8
M_2	9.0	10.2	9.6	9.3		9.0	10.4 10.5	10.4	9.8	9.9	9.7	10.8 10.7	88.5
M_3	7.3			8.7			9.4		9.8		9.3	9.6	
Length metaconid-metastylid													
P_2	12.3	11.5	12.4	11.5		11.8	12.0 12.4	12.4	11.1	11.6		12.7 12.9	12.8
P_3	13.8	14.0	14.7	14.9		14.9	13.7 13.6	13.2	14.1	8.9	14.4	14.6 14.6	

MEASUREMENTS IN MILLIMETERS

	Neohipparion floresi										N. arellanoi		
	3334	3335	3336	3337	3338	3339	5073	5075	5076	5077	5078	5072	5074
P_1	13.1	13.4	13.6	13.9		13.8	13.8 13.7	13.5		13.3	14.2	13.9 14.0	11.8
M_1	12.5	13.0	13.0	12.6		12.9	12.0 12.3	11.5	11.9	12.8	12.2	13.5 13.2	13.8
M_2	12.1	12.6	13.2	12.4		12.4	12.3 12.3	12.4	11.7	12.7	12.3	13.7 13.9	12.2
M_3	10.8		11.4	11.5			11.9		11.8		12.0	13.1 12.9	
Anteroposterior length at crown and base from end of paralophid to posterior edge of endostylid													
P_4	19.9×17.2	21.2	20.5×17.1	20.1		24.2	20.7 20.0	18.8			20.8	19.4	22.8
M_2	19.3×15.9	20.8	20.3×17.2	20.4		22.8	20.4 20.4	18.7	18.5		20.0	20.3 20.9	23.5
M_3	18.4×21.2			20.1					21.5		22.8	23.5 23.3	
Crown height from base to top of metaconid													
P_4	49.3		46.1		49.7								
M_2	58.7		57.2		54.4								
M_3	61.8				61.7								

† Where two measurements are used in the same column, they refer to the right and left sides of the same individual.

DECIDUOUS UPPER TEETH—early stages of wear, *N. floresi* n. sp., CIT 3332

Length across occlusal surfaces	
DP^2–DP^4	81.5
DP^2–DP^3	55.0
DP^3–DP^4	52.2
Width across mesostyle and posterior end of protocone	
DP^2	17.0
DP^3	16.0
DP^4	15.3
Length of protocone	
DP^2	8.0
DP^3	8.2
DP^4	10.0
Anteroposterior length at crown and at base—parastyle to mesostyle	
DP^2	29.1×27.1
DP^3	25.3×21.1
DP^4	26.9×20.9
Crown height from base of enamel to tip of parastyle	
DP^2	16.6
DP^3	17.8
DP^4	28.2

DECIDUOUS LOWER TEETH—early stages of wear, *N. floresi*, n. sp., CIT 3505.

Length across occlusal surfaces	
DP_2–DP_4	81.2
DP_2–DP_3	54.0
DP_3–DP_4	53.7
Width across metaconid-protoconid	
DP_2	7.3
DP_3	7.4
DP_4	7.0
Length metaconid-metastylid	
DP_2	13.8
DP_3	13.9
DP_4	13.2
Anteroposterior length at crown and base from end of paralophid to posterior edge of endostylid	
DP_2	28.7
DP_3	25.2
DP_4	27.3×22.5
Crown height from base to top of metaconid	
DP_4	31.0

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A CHECK-LIST OF THE CRETACEOUS AND TERTIARY VERTEBRATES OF NEW JERSEY

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ABSTRACT—Vertebrate fossils recorded from the Cretaceous and Tertiary of New Jersey are listed according to both formation and systematic position. Where possible, original descriptions are cited and the location of type material is indicated.

INTRODUCTION

DURING the summer of 1954, through the courtesy of Dr. Horace G. Richards, the writer had the opportunity of studying the collection of fossil vertebrates of the Academy of Natural Sciences of Philadelphia. The present check-list is partly an outgrowth of this study.

This check-list differs from previous lists of New Jersey vertebrates in the organization of the subject matter into a systematic list, a summary of the forms from each formation and the inclusion of catalog numbers for type specimens. Recent revisions of generic and specific names by several authors have been included, several new occurrences are recorded, and the stratigraphic zones of some specimens in old collections are reinterpreted.

Specimens in the old collections have been referred to stratigraphic positions by: (1) examining the lithology of the matrix, if any, of the specimens, (2) referring to the original description to see if the specimen was referred to any formation and (3) assuming those recorded from known localities were within the outcropping boundary of the exposed formation.

The species within parentheses followed by a question mark, in the summary of forms from the formations, are doubtfully recorded from the listed formation.

The writer was unable to locate some of the type specimens owned by the Academy and other institutions, and these are marked as missing. Fossil fish are not included in the systematic list, as the taxonomy of this group is in need of revision.

The taxonomy of the reptiles and birds is adapted from Romer (1945), and that of the mammals from Simpson (1945).

The following abbreviations are used in the list for the museums:

ANSP—Academy of Natural Sciences of Philadelphia
AMNH—American Museum of Natural History
Rutgers U.—Rutgers University Museum
YPM—Yale Peabody Museum
NJGS—New Jersey Geological Survey
USNM—United States National Museum

The terms "type" and "holotype" are used without distinction, being quoted from the respective museum labels.

Many fossil vertebrates listed as coming from the "greensand" of New Jersey have been previously referred to the Hornerstown formation of Paleocene age (Rapp, 1944), although the fossils are undoubtedly Cretaceous. These specimens came from localities where the Hornerstown formation is underlain by a lithologically identical greensand of Cretaceous age. The exact relationship of this "middle greensand unit" will be dealt with in another paper on stratigraphy by the author. At present this unit is referred to as the "middle greensand" of Cretaceous age.

The systematic list refers the specimens from the "middle greensand unit" to the Hornerstown formation, but they are more properly split into a Cretaceous group and a Paleocene group as in the summary of forms from the formations. There is doubt about the correct age reference of some of these genera and species, and more collecting and field work will be necessary to clarify this situation.

Some genera, such as *Thoracosaurus*, formerly referred to the Upper Cretaceous may actually belong in the Tertiary and not occur in older sediments. Other genera, such

as *Osteopygis*, seem to range from the Cretaceous up into the Paleocene.

SUMMARY OF FORMS FROM THE FORMATIONS

Raritan formation

Plesiosauria
"Taphrosaurus" lockwoodi Cope (nomen vanum)
Dinosaur footprints—Pit at Woodbridge

Matawan group

Chelonia
Agomphus petrosus Cope

Merchantville formation

Selachii
Isurus appendiculatus Agassiz
Squalicorax pristodontus Morton
Actinopterygii
Pycnodont (sp. indescr.)
Chelonia
(*Trionyx halophila* Cope)?
Podocnemis (sp. indescr.)
Squamata
Clidastes? sp.
Mosasaurus sp.
Crocodilia
Unidentified specimen
Ornithischia
Ornithotarsus immanis Cope

Woodbury formation

Selachii
Isurus elegans Agassiz
I. texana Roemer
Isospondyli
Enchodus ferox Leidy
Ischyrhiza mira Leidy
Squamata
Mosasaurus sp.
Ornithischia
Ornithotarsus immanis Cope
Hadrosaurus foulkii Leidy

Marshalltown formation

Plesiosauria
"Elasmosaurus" orientalis Cope
Squamata
Clidastes iguanavus Cope
Ornithischia
Hadrosaurus minor Marsh

Wenonah formation

Selachii
Isurus elegans Agassiz
I. texana Roemer
Squalicorax pristodontus Morton

Monmouth group

Isospondyli
Enchodus oxystomus Cope

Navesink formation

Selachii
Isurus desorii Agassiz
I. mudgei Cope
I. appendiculatus Agassiz
Actinopterygii
Pycnodus phaseolus Hay
Isospondyli
Enchodus ferox Leidy
E. tetraecus Cope
Acanthopterygii
Beryx insculptus Cope
Squamata
(*Mosasaurus copeanus* Marsh)?
Mosasaurus sp.
Crocodilia
(*Goniopholis rogersii* Owen)?
(*Thoracosaurus neocesariensis* DeKay)?

Red Bank formation

Acanthopterygii
Beryx insculptus Cope

"Middle greensand" of Cretaceous age

Selachii
Hybodontid?
Isurus desorii Agassiz
I. texana Roemer
I. appendiculatus Agassiz
Squalicorax falcatus Agassiz
S. pristodontus Morton
Batoidea
Myliobatis obesus Leidy
Chimaerae
Leptomylus cookii Cope
L. densus Cope
L. forbex Cope
Isospondyli
Enchodus ferox Leidy
Ischyrhiza mira Leidy
Chelonia
Bothremys cooki Leidy
Taphrosphys molops Cope

Toxochelys atlantica Zangerl
Osteopygis emarginatus Cope
Agomphus firmus Leidy
A. masculinus Wieland
A. pectoralis Cope
A. tardus Wieland
A. turgidus Cope
Adocus agilis Cope
A. beatus Leidy
A. pravus Leidy
Plesiosauria
Cimoliasaurus magnus Leidy
"Plesiosaurus" brevifemur Cope (nomen vanum)
Squamata
Ancylocentrum hungerfordii Chaffee
Baptosaurus fraternus Marsh
Nectoportheus validus Cope
Tylosaurus laticaudus Marsh
T. sectorius Cope
Mosasaurus depressus Cope
M. miersii Marsh
M. oarthrus Cope
M. princeps Marsh
Crocodilia
Goniopholis ferox Marsh
G. fraterculus Cope
G. natator Troxell
G. natator oweni Troxell
G. rogersii Owen
Saurischia
Dryptosaurus aquilunquis Cope
Ornithischia
Hadrosaurus foulkii Leidy
H. minor Marsh

Hornerstown formation

Selachii
Isurus acuminatus Morton
I. cuspidata Agassiz
I. elegans Agassiz
I. lanceolatus Morton
Carcharodon auriculatus Blainville
C. angustidens Agassiz
C. megalodon Agassiz
C. carcharias Linnaeus
Squalicorax falcatus Agassiz
S. pristodontus Morton
Galeocerdo aduncus Agassiz
Hemipristis serra Agassiz
Glyphis egertoni Agassiz
Batoidea
Myliobatis leidyi Hay
M. rectidens Cope
M. obesus Leidy
M. undulatus Chaffee
Chimaerae
Edaphodon stenobryus Cope
E. tripartitus Cope
E. laterigerus Cope
E. smockii Cope
E. incrassatus Cope
E. fecundus Cope
E. mirificus Leidy
E. miersii Marsh
E. divaricatus Cope
E. solidulus Cope
E. latidens Cope
Bryactinus amorphus Cope
Isotaenia neocaesariensis Cope
Leptomylus cookii Cope
L. densus Cope
L. forbex Cope
Actinopterygii
(*Pycnodus robustus* Leidy)?
Isospondyli
Conosaurus bowmani Gibbes
Saurocephalus leanus Hays
Cylindracanthus ornatus Leidy
Enchodus ferox Leidy
Ischyrhiza mira Leidy
Fish, insertae sedis
Sphagepoea aciculata Cope
Chelonia
Amblypeza entellus Hay
Taphrosphys leslianus Cope
T. longinuchus Cope
T. nodosus Cope
T. strenuus Cope
T. sulcatus Leidy
"Lytoloma" angusta Cope (nomen vanum)
Osteopygis emarginatus Cope
Catapleura ponderosa Cope
Homorophus insuetus Cope
Zygoramma microglypha Cope
Z. striatula Cope
Adocus lacer Hay
A. punctatus Marsh
A. syntheticus Cope
Trionyx prisca Leidy
Squamata
(*Palaeophis halidanus* Cope)?
Crocodilia
Thoracosaurus meirsanus Troxell
T. mullicensis Troxell
T. neocesariensis DeKay

T. basitruncatus Owen
T. glyptodon Cope
T. obscurus Leidy
T. pneumaticus Cope
Bottosaurus harlani Meyer
B. tuberculatus Cope
Aves
Graculavus pumilus Marsh
Limosavis velox Marsh
Telmatornis affinis Marsh
T. priscus Marsh
Palaeotringa littoralis Marsh
P. vagans Marsh
P. vetus Marsh
Laornis edvardsianus Marsh

Vincentown formation

Selachii
Acrodus humilis Leidy
Hexanchus primigenius Agassiz
H. ensis Leidy
Isurus desorii Agassiz
I. acuminatus Morton
Carcharodon megalodon Agassiz
Acanthopterygii
Enchodus ferox Leidy
Histiophorus homalorhamphus Cope
Unidentified
fish spines
Chelonia
Rhetechelys platyops Cope
Peritresias ornatus Leidy
Squamata
Palaeophis littoralis Cope
Cheilophis huerfanoensis Gilmore
Crocodilia
(*Thoracosaurus basifissus* Owen)?
Thoracosaurus neocesariensis DeKay
T. basitruncetus Owen
Crocodylus sp.

Manasquan formation and
Shark River member

Selachii
Hexanchus howelli Reed
H. primigenius Agassiz
H. ensis Leidy
Isurus desorii Agassiz
I. hastalis Agassiz
I. acuminatus Morton
I. cuspidata Agassiz
I. elegans Agassiz
I. texana Roemer
I. appendiculatus Agassiz
I. levis Gibbes
I. lanceolatus Morton
Carcharodon auriculatus Blainville
C. polygurus Morton
Squalicorax falcatus Agassiz
S. pristodontus Morton
Ginglymostoma obliquum Leidy
Galeocerdo aduncus Agassiz
G. contortus Gibbes
Hemipristis serra Agassiz
Glyphis egertoni Agassiz
Batoidea
Pristis amblodon Cope
P. curvidens Leidy
Myliobatis bisulcatus Marsh
M. fastigatus Leidy
M. glottoides Cope
M. magister Leidy
M. rugosus Leidy
M. leidyi Hay
M. obesus Leidy
M. pachyrhizodus Fowler
Rhinoptera dubia Leidy
Aetobatis perspicuus Leidy
Chimaeridae
Edaphodon eocaenus Cope
Isospondyli
Cylindracanthus ornatus Leidy
C. acus Cope
Enchodus serrulatus Fowler
Acanthopterygii
Phyllodus elegans Marsh
Histiophorus antiquus Marsh
H. parvulus Marsh
Embalorhynchus kinnei Marsh
Chelonia
(*Osteopygis emarginatus* Cope)?
Lembonax insularis Cope
L. polemicus Cope
L. propylaeus Cope
Chelonia parvitecta Cope
Squamata
Palaeophis grandis Marsh
P. halidanus Cope
P. littoralis Cope
Pterosphenus cf. *P. schucherti* Lucas
Crocodilia
(*Crocodylus sericodon* Cope)?
Crocodylus serratus Cope
C. squankensis Marsh
Gavialis minor Marsh
Aves
Diatryma regens Marsh
Mammalia
Anchippodus riparius Leidy

Kirkwood formation

Selachii
Hexanchus primigenius Agassiz
Isurus desorii Agassiz
I. acuminatus Morton
I. sillimani Gibbes
I. cuspidata Agassiz
I. elegans Agassiz
I. appendiculatus Agassiz
I. lanceolatus Morton
Carcharodon auriculatus Blainville
C. polygurus Morton
Galeocerdo aduncus Agassiz
G. contortus Gibbs
G. latidens Agassiz
Hemipristis serra Agassiz
Glyphis egertoni Agassiz
Sphyrna prisca Agassiz
Batoidea
Myliobatis kummeli Fowler
Rhinoptera dubia Leidy
Plinthicus stenodon Cope
Isospondyli
Saurocephalus leanus Hay?
Enchodus gentryi Cope
Acanthopterygii
Crommyodus irregularis Cope
Phyllodus curvidens Marsh
Dictyodus silovianus Cope
Chelonia
Testudo trionythus
Procolpochelys grandaera Leidy
Aves
Moris loxostyla Cope
Sula atlantica Shufeldt
Mammalia
Ammodon leidyanus Marsh
Desmathyus antiquus Marsh
Diceratherium matutinum Marsh
D. cf. *D. cooki* Peterson

SYSTEMATICS

Class REPTILIA

Subclass ANAPSIDA

Order CHELONIA

Suborder PLEURODIRA

Family PELOMEDUSIDAE

Genus AMBLYPEZA Hay (1908, p. 122)

Amblypeza entellus Hay (1908, p. 122)—N. J. Hornerstown fm. Type: NJGS 6613, validity doubtful, see Zangerl (1948, p. 42).

Genus BOTHREMYS Leidy (1865, p. 110–120)

Bothremys cooki Leidy (1865, p. 110–120)—Barnsboro, Hornerstown fm. Type: Rutgers U. 1.KV-6.

Genus PODOCNEMIS Wagler

Podocnemis?—New Jersey, ANSP 9370.
Podocnemis sp.—Maple Shade, N. J., Merchantville fm., ANSP, no catalog no.

Genus TAPHROSPHYS Cope (1868b, p. 735)

Taphrosphys leslianus Cope (1869–70, p. 159)—Hornerstown, Hornerstown fm. Type: AMNH 1467.
T. longinuchus Cope (1860–70, p. 159)—Medford, Hornerstown fm. Type: AMNH 1125.
T. molops Cope (1869–70, p. 158)—Barnsboro, Hornerstown fm. Type: AMNH 1472.
T. molops Cope—Pemberton, N. J., Hornerstown fm., ANSP 9213–9216.
T. nodosus Cope—(1869–70, p. 159)—Hornerstown, Hornerstown fm. Type: AMNH 1480.
T. strenuus Cope (1869–70, p. 166b)—Barnsboro, Hornerstown fm. Type: AMNH 1126.
T. sulcatus Leidy (1856b, p. 303)—Tinton Falls, Hornerstown fm. Type: Rutgers 1-K.V.7.
T. sulcatus Leidy—Mullica Hill, Hornerstown fm.? ANSP 9666–7–8.

Suborder CRYPTODIRA

Family THALASSEMYDIDAE

Genus "LYTOLOMA" Cope (1869–70, p. 105) nomen vanum (Zangerl, 1953, p. 145)

"Lytoloma" angusta Cope (1869–70, p. 145)—Birmingham, N. J., nomen vanum, see Zangerl (1953, p. 145). Type: AMNH 1133.
"L." jeanesii Cope—Barnsboro, Hornerstown fm., Type: missing, referred specimen AMNH 1473 is a mixed specimen, nomen vanum, see Zangerl (1953, p. 145).

Genus CATAPLEURA Cope (1869–70, p. 143)

Catapleura ponderosa Cope (1871, p. 46)—Hornerstown, Hornerstown fm. Type: AMNH 1475.
C. repanda Cope (1868b, p. 147)—Barnsboro, Hornerstown fm. Type: AMNH 2353.
mortoni Agassiz (in Leidy 1865, p. 43) (*Atlantochelys*) Burlington Co. Type: ANSP 9234.

Family DERMATEMYDIDAE

Genus AGOMPHUS Cope (1869–70, p. 125)

Agomphus firmus Leidy (1856, p. 303)—Tinton Falls, Hornerstown fm. Type: Rutgers 1.K.V.8.
A. masculinus Wieland (1905, p. 437)—Barnsboro, Hornerstown fm. Type: YPM 671.
A. pectoralis Cope (1868a, p. 236)—Medford, Hornerstown fm. Type: AMNH 1478.
A. petrosus Cope (1868a, p. 236)—Gloucester, Camden Co., Matawan Group. Type: AMNH 1482.
A. tardus Wieland (1905, p. 430)—Birmingham, Hornerstown fm. Holotype: YPM 774.
A. turgidus Cope (1869-70, p. 125)—Mount Holly Hornerstown fm. Type: AMNH 1481.
A. turgidus Cope—Hornerstown, Hornerstown fm. YPM 900.

A. sp.—Sewell, Hornerstown fm., ANSP. no number.

Genus HOMOROPHUS Cope (1870a, p. 552)

Homorophus insuetus Cope (1870a, p. 552)—Pemberton, Hornerstown fm. Type: missing.

Genus ZYGORAMMA Cope (1870a, p. 552)

Zygoramma microglypha Cope (1871, p. 44)—Birmingham, Hornerstown fm. Type: AMNH 6129.
Z. striatula Cope (1870a, p. 550)—Pemberton, Hornerstown fm. Type: AMNH 2358.

Genus ADOCUS Cope (1868a, p. 235)

Adocus agilis Cope (1868a, p. 235)—Barnsboro, Hornerstown fm. Type: AMNH 1135.
A. beatus Leidy (1865, p. 107, 119)—Mullica Hill, Hornerstown fm. Type: ANSP 9184.
A. lacer Hay (1908, p. 241)—N.J., Hornerstown fm.? Type: AMNH 1350.
A. lacer Hay—N. J., Hornerstown fm., greensand. Type: ANSP 9598.
A. pravus Leidy (1856b, p. 303)—Tinton Falls, Hornerstown fm.? Type: Rutgers 1-KV-9.
A. punctatus Marsh (1890, p. 178)—Hornerstown, Hornerstown fm. Holotype: YPM 780.
A. syntheticus Cope (1870a, p. 515)—Barnsboro, Hornerstown fm. Type: AMNH 1466.

Family TESTUDINAE

Genus TESTUDO Linnaeus (1758, p. 197)

Testudo—Burlington Co., Miocene, ANSP 9217.
T. trionythus—Author unknown—Farmingdale, Miocene, ANSP 10191.

Family TOXOCHELYIDAE

Genus TOXOCHELYS Cope (1873, p. 10)

Toxochelys atlantica Zangerl (1953, p. 146) (*"Lytoloma" wielandi* Hay)—Barnsboro, Middle bed. Hornerstown fm. Holotype: YPM 625.

Genus RHETECHELYS Hay (1908, p. 161)

Rhetechelys platyops Cope (1867, p. 41) (*Euclastes*)—Hurffville, Vincentown fm. Type: ANSP 10187.

Genus OSTEOPYGIS Cope (1868b, p. 147)

All *Osteopygis* spp. (except *"O." sopitus*) are *O. emarginatus* Cope, see Zangerl, R. (1952, p. 273).

Osteopygis borealis Wieland (1904, p. 129) (*Propleura*) Hornerstown, Hornerstown fm. Type: YPM 778.
O. chelydrinus Cope (1868b, p. 147)—Barnsboro, Hornerstown fm. Type: AMNH 1131.
O. emarginatus Cope (1868b, p. 147)—Barnsboro, Hornerstown fm. Type: AMNH 1344.
O. emarginatus Cope (1869–70, p. 145)—Birmingham, Hornerstown fm., AMNH 1133, (mandible only).
O. erosus Cope (1875, p. 258)—Barnsboro, Hornerstown fm. Type: AMNH 1130.
O. gibbi Wieland (1904, p. 118)—Barnsboro, Hornerstown fm., greensand. Holotype: YPM 783.
O. molaria Hay (1908, p. 160) (*Erquelinnesia*)—Birmingham Hornerstown fm. Type: AMNH 9220.
O. platylomus Cope (1869a, p. 89)—Pemberton, (from Manasquan?) prob. Hornerstown fm. Type formerly at ANSP 14676.
O. robustus Hay (1908, p. 134)—Birmingham, Hornerstown fm. Type: AMNH 2360.
"O." sopitus Leidy (1865, p. 104, 119) (*Chelone*)—Mullica Hill, Navesink fm. Type: ANSP 9223, nomen vanum see Zangerl (1953, p. 207).
Osteopygis sp.—Vincentown, N. J., Hornerstown fm.: ANSP 9221-8.
O. sp.—New Jersey. ANSP 9209.

Family CHELONIDAE

Genus PERITRESIAS Cope (1868b, p. 735)

Peritresias ornatus Leidy (1856b, p. 303)—Burlington Co., Vincentown limestone. Type: ANSP 9218.

Genus LEMBONAX Cope (1869–70, p. 444)

Lembonax insularis Cope (1872, p. 16)—Vincentown, Manasquan fm.? Type: AMNH 2347.
L. polemicus Cope (1869–70, p. 168)—Farmingdale, Manasquan fm.? Type: AMNH 1134.
L. propylaeus Cope (1872, p. 15)—Farmingdale, Manasquan fm. Type: AMNH 1310.
L. sp.—Vincentown, Manasquan fm. Type: ANSP 9229.

Genus CHELONIA Brongniart (1799, p. 184)

Chelonia parvitecta Cope (1869-70, p. 155)—Squankum, Manasquan fm. Type: AMNH 1318.

Genus PROCOLPOCHELYS Hay (1908, p. 215)

Procolpochelys grandaera Leidy (1851, p. 329)—Salem, N. J., Miocene? Type: ANSP 9212.

Family TRIONYCHIDAE

Genus TRIONYX Geoffroy (1832, p. 320)

Trionyx halophila Cope (1869b, p. 12) (*Amyda*)—Camden Co. and Summit Bridge, New Co., Del., Merchantville fm.? Type: AMNH 1476.
T. halophila Cope (*Amyda*)—Camden Co., N. J., ANSP 9198.
T. lima Cope (1869b, p. 12) (*Amyda*)—Cumberland Co. Type: AMNH 1167.
T. prisca Leidy (1851, p. 329) (*Amyda*)—Monmouth Co., Hornerstown fm. Type: Rutgers 1-K.V.10.

Unidentified CHELONIA

1. Shelltown, Ocean Co., N.J., ANSP 9219.
2. ramus of lower jaw—Alloway, N.J., Vincentown fm., ANSP 9200.
3. Marlton, N. J., Hornerstown fm., ANSP no number.

Order SAUROPTERYGIA
Suborder PLESIOSAURIA
Infraorder PLIOSAUROIDEA
Insertae sedis
Genus "TAPHROSAURUS" Cope (1870b, p. 274)

"Taphrosaurus" lockwoodi Cope (1869–70, p. 40)—nomen vanum, see Welles (1952), Raritan. Type: lost.

Infraorder PLESIOSAUROIDEA
Family ELASMOSAURIDAE
Genus CIMOLIASAURUS Leidy (1851, p. 325)

Cimoliasaurus planior Leidy (1870, p. 22) (*Discosaurus*)—nomen vanum, see Welles (1952), N.J. Type: lost.
C. vetustus Leidy (1851, p. 326) (*Discosaurus*)—nomen vanum, see Welles (1952), Burlington Co., N.J. Type: ANSP 9183, 9173.
C. magnus Leidy (1851, p. 325; 1854, p. 72)—Burlington Co. Type: ANSP 9235.

Family ELASMOSAURIDAE
Insertae sedis

"Plesiosaurus" brevifemur Cope (1875, p. 256) nomen vanum, see Welles (1952, p. 105)—Barnsboro, Hornerstown fm. Type: lost.
"Elasmosaurus" orientalis Cope (1869-70, p. 313) nomen vanum, see Welles (1952, p. 104)—Swedesboro, Marshalltown fm. Type: AMNH 1409.

Order SQUAMATA
Suborder LACERTILIA
Infraorder PLATYNOTA
Family MOSASAURIDAE
Genus ANCYLOCENTRUM Schmidt (1927, p. 59)

Ancylocentrum hungerfordi Chaffee (1939)—Greensand, Sewell, N.J., Hornerstown fm. Type: NJGS 9827.

Genus BAPTOSAURUS Marsh (1870b, p. 2)

Baptosaurus fraternus Marsh (1869, p. 397)—Hornerstown fm. Holotype: YPM 445.
B. platyspondylus Marsh (1869, p. 395)—Hornerstown fm. Holotype: YPM 444.

Genus CLIDASTES Cope (1868a, p. 233)

Clidastes? (tooth only)—Maple Shade, N. J., Merchantville fm., ANSP 19642.
C. conodon Cope (1881, p. 587)—Freehold, Navesink? fm. Type: Rutgers U. 1-K.V.11.
C. iguanavus Cope (1868a, p. 233)—Swedesboro, Marshalltown fm. Holotype: YPM 1601.
C. validus Cope (1868b, p. 181) (*Nectoportheus*)—Barnsboro, Hornerstown fm. Type: AMNH 1395.

Genus DIPLOTOMODON Leidy (1868a, p. 202)

Diplotomodon horrificas Leidy—ANSP 9680. Type: lost.

Genus POLYGONODON Leidy (1856a, p. 221)

Polygonodon vetus Leidy (1856a, p. 221)—N.J., Type: lost.

Genus TYLOSAURUS Marsh (1872b, p. 147)

Tylosaurus laevis Owen (1849, p. 380)—(*Macrosaurus*)—N.J., ANSP 9632-3, 8533-4.
T. laticaudus Marsh (1870b, p. 2)—Hornerstown, N.J., Hornerstown fm. Type: lost.
T. mitchilli DeKay (1830, p. 140) (*Macrosaurus* Owen)—Monmouth Co. Type: lost.
T. rapax Hay (1902, p. 473)—N.J. Type: AMNH 1490.
T. rapax Hay—Monmouth Co., ANSP 9641.
T. sectorius Cope (1871, p. 41)—Birmingham, Hornerstown fm. Type: AMNH 1401.
T. sp. (*Liodon*)—Vincentown, N. J., Hornerstown fm.? ANSP 9669–70.

Genus MOSASAURUS Conybeare (1808, p. 145)

Mosasaurus copeanus Marsh (1869, p. 393)—Marlboro, Monmouth Co., Navesink fm. Holotype: YPM 312.
M. dekayi Bronn (1838)—N.J., ANSP 8682, 8672–81, 8683–97, 8670–1, 8546–7. Type: missing.
M. depressus Cope (1869-70, p. 196)—Birmingham, Hornerstown fm. Type: lost.
M. fulciatus Cope (1869–70, p. 194)—Monmouth Co. Type: AMNH 1398.
M. maximus Cope (1869c, p. 262)—Middletown, N.J., Monmouth Co. Type: AMNH 1389.
M. meirsii Marsh (1869, p. 395)—Hornerstown, Hornerstown fm. Holotype: YPM 443.
M. oarthrus Cope (1869-70, p. 196)—Barnsboro, Hornerstown fm. Type: AMNH 1392.
M. princeps Marsh (1869, p. 392)—Hornerstown, Hornerstown fm. Type: YPM 430.
M. sp.—St. Georges, Del., Navesink fm.? ANSP 8500–11.
M. sp.—N.J., ANSP 8523, 8462, 8552.
M. sp.—Hanover—Burlington Co., ANSP 8522.
M. sp.—Lumberton, N.J., Hornerstown fm., (several specimens), ANSP 8698, 87, 8531, 19–20, 40, 15, 8482–3, 76, 77.
M. sp.—Burlington Co., ANSP 8524, 29, 37, 44, 45, 72, 8502, 8505–6, 21.
M. sp.—Burlington, N.J., ANSP 8541–3.
M. sp.—Woodbury, N.J., Woodbury fm., ANSP 8517, 8468, 8507.
M. sp.—Maple Shade, N.J., Merchantville fm., ANSP 15191.
M. sp.—Vincentown, N.J., Hornerstown fm., ANSP 8530.
M. sp.—Mount Holly, N.J., Hornerstown fm.?, ANSP 8463.
M. sp.—Monmouth Co., N.J., ANSP 8475, 78, 79, 80, 81, 8504, 8510, 13, 14, 16, 03, 12, 8509, 26, 27, 35, 8532, 8548–51, 8464–7, 69, 74, 73, 71, 70.
M. sp.—Woodstown, N.J., Hornerstown fm., ANSP 8528.
M. sp.—Ayerstown, N.J., Hornerstown fm., ANSP 15234.
M. sp.—N.J. (jaws and teeth) uncatalogued, ANSP.

Suborder SERPENTES
Family PALAEOPHIDAE
Genus PALAEOPHIS Owen (1839, p. 209)

Palaeophis grandis Marsh (1869, p. 397)—nr. Shark River, Manasquan fm., Monmouth Co. Holotype: YPM 2762.
P. halidanus Cope (1868a, p. 235)—Squankum, Manasquan fm. Holotype: YPM 2763.
P. littoralis Cope (1868a, p. 234)—Squankum, Manasquan fm. Type: AMNH 2392.
P. littoralis Cope—Vincentown, N.J., Vincentown fm., USNM 11753.
P. littoralis Cope—Shark River, N.J., Manasquan fm., ANSP 8995.

Genus PTEROSPHENUS Lucas (1899, p. 637)

Pterosphenus cf. *P. schucherti* Lucas (1899)—Vincentown, Manasquan fm., ANSP 8996. Type: USNM 4047 from Ala.

Family COLUBRIDAE?
Genus CHEILOPHIS Gilmore (1938, p. 79)

Cheilophis huerfanoensis Gilmore—Vincentown, N.J., Vincentown fm., YPM 18625. Type: AMNH 5195 from Colo.

Order CROCODILIA
Suborder MESOSUCHIA
Family TELEOSAURIDAE
Doubtful identifications

Teleosaurids?—Vincentown, Hornerstown fm., ANSP 9425–34.
Teleosaurdids?—Mt. Holly, Hornerstown fm., ANSP 9146.
Teleosaurids?—Jobstown, Hornerstown fm., ANSP 9163–5.
Teleosaurids?—Mantua, Hornerstown fm., ANSP 9407.
Teleosaurids?—N.J., Hornerstown fm., ANSP 9649–52.
Teleosaurids?—West Jersey Marl pits, Sewell, Hornerstown fm., no number ANSP.

Family GONIOPHOLIDAE
Genus GONIOPHOLIS Owen (1842, p. 69)

Goniopholis ferox Marsh (1871, p. 104) (*Hyposaurus*)—Birmingham, greensand, Hornerstown fm. Holotype: YPM 2794.
G. fraterculus Cope (1869–70, p. 82) (*Gavialis*)—Birmingham, Hornerstown fm. Type: AMNH 2198.
G. natator Troxell (1925, p. 496), (*Hyposaurus*)—Hornerstown fm., marl. Holotype: YPM 985.
G. natator oweni Troxell (1925, p. 505) (*Hyposaurus*)—Barnsboro, N.J., Hornerstown fm., marl. Holotype: YPM 753.
G. rogersii Owen (*Hyposaurus*)—N.J., ANSP 8640–69.
G. rogersii Owen (*Hyposaurus*)—White Horse, Camden, N. J. ANSP 8627–39.
G. rogersii Owen (*Hyposaurus*)—Burlington Co., ANSP 9681.
G. rogersii Owen (*Hyposaurus*)—Blackwood, ANSP 9682, 9683–95, 9656–95, 9679, 9631, 9642, 43, 44, 45, 34–37.
G. rogersii Owen (*Hyposaurus*)—Birmingham, Hornerstown fm., ANSP 9678.
G. rogersii Owen (1849, p. 382) (*Hyposaurus*)—Birmingham, N.J., Type: missing.
G. rogersii Owen—New Castle Co., Del., Navesink fm.?, ANSP 9648.
G. sp.—Blackwood, Hornerstown fm., ANSP 9538–40.
G. sp.—Hornerstown, Hornerstown fm., YPM 275.

Suborder EUSUCHIA
Family CROCODYLIDAE
Genus THORACOSAURUS Leidy (1852, p. 35)

Thoracosaurus basifissus Owen (1849, p. 380)—Vincentown, Vincentown fm? Type at Brit. Museum?
T. meirsansus Troxell (1925, p. 22b)—Hornertown, Hornerstown fm. Holotype: YPM 404.
T. neocesarienis DeKay (1833, p. 156)—Big Timber Creek, Glou. Co., N.J., Vincentown limestone, ANSP 9374, 9371. Type: lost.
T. neocesariensis DeKay—Blackwood, Vincentown fm., from limestone, ANSP 9364.
T. neocesariensis DeKay—Mt. Holly, Navesink fm.?, ANSP 9435, 9358.
T. neocesariensis DeKay—N.J., ANSP 9437, 9361–3, 9365, 9415, 9420–4, 9357.
T. neocesariensis DeKay—Vincentown, N.J., Hornerstown fm.?, ANSP 10079.
T. sp.—Birmingham, N.J., Hornerstown fm., ANSP 9553.
T. sp.—Gloucester Co., ANSP 9382.
T. sp.—Hornerstown Greensand, YPM 278, 280, 281.
T. sp.—Mullica Hill, Hornerstown fm.?, YPM 283.
T. basitruncatus Owen (1849, p. 380)—Big Timber Creek, Glou, Co., Vincentown fm., ANSP 9436, 9169, 9383, 9355–6. Type: missing.
T. brevispinus Cope (1867, p. 39)—Burlington Co. Type: AMNH 1445.
T. brevispinus Cope—Burlington Co., Rutgers U. 1-K.V.13.
T. cordatus Cope (1869–70, p. 73)—N.J. Type: AMNH 2206.
T. glyptodon Cope (1869–70, p. 74)—Barnsboro, N.J., Hornerstown fm. Type: ANSP 9388–93.
T. obscurus Leidy (1865, p. 115)—Barnsboro, Hornerstown fm. Type: Rutgers U. 1-K.V.12.
T. obscurus Leidy—Pemberton, Hornerstown fm., ANSP 9185–7.
T. pneumaticus Cope (1872, p. 11)—Harrisonville, Hornerstown fm. Type: AMNH 2217.

Genus CROCODYLUS Laurenti (1768, p. 53)

Crocodylus sericodon Cope (1867, p. 43)—Miocene?, N.J. Type: missing.
C. sericodon Cope—Miocene?, N. J., AMNH 2196.
C. serratus Cope (1872, p. 17)—Farmingdale, Manasquan fm. Type: lost.

C. squankensis Marsh (1869, p. 391)—Squankum, Manasquan fm. Type: lost.

Mislabeled specimens, probably THORACOSAURUS sp.

Crocodylus sp.?—Vincentown, N.J., ANSP 9170, 9412, 9190–5, Hornerstown fm.?
C. sp.?—Burlington Co., Medford, ANSP 9232: Pemberton, ANSP 9167. 9411, 9387, Hornerstown fm.
C. sp.?—Jobstown, Hornerstown fm., ANSP 9166.
C. sp.?—St. George, Del., Navesink fm.? ANSP 9168.
C. sp.?—Mullica Hill, Navesink fm.?, ANSP 9176–81.
C. sp.?—Birmingham, Hornerstown fm., ANSP 1524.
C. sp.?—Hornerstown, Hornerstown fm., ANSP 10216, 9394–407.
C. sp.?—Arneytown, Hornerstown fm., ANSP 9376–7.
C. sp.?—Big Timber Creek, Glou. Co., Vincentown fm., from limestone, ANSP 9372–3.
C. sp.?—Gloucester, N.J., ANSP 9359–60.
C. sp.?—Barnsboro, N.J., Hornerstown fm., ANSP 9386.
C. sp.?—Sewell, N.J., Hornerstown fm., ANSP 15068.
C. sp.?—Maple Shade, N.J., Merchantville fm., ANSP 10217.
C. sp.?—New Jersey, ANSP 8863–6, 9147–9, 9148–9.

Family ALLIGATORIDAE
Genus BOTTOSAURUS Agassiz (1849, p. 169)

Bottosaurus harlani Meyer (1832, p. 108)—Birmingham, Burlington Co., Hornerstown fm. Type: ANSP 9226, Paratypes 9227, 9174.
B. harlani Meyer—Pemberton, Hornerstown fm., ANSP 9156–9160, 9205–8.
B. harlani Meyer—Vincentown, Hornerstown fm.?, ANSP 9230.
B. harlani Meyer—Monmouth Co., ANSP 9381.
B. tuberculatus Cope (1869–70, p. 230)—Birmingham, Hornerstown fm., Type: ANSP 9233.
B. tuberculatus Cope (1869–70, p. 230)—Tinton Falls. Type: lost.

Family GAVIALIDAE
Genus GAVIALIS Oppel (1811, p. 19)

Gavialis minor Marsh (1870a, p. 97)—Shark River, Manasquan fm. Holotype: YPM 282.
G. sp.—Pemberton, Hornerstown fm., ANSP 8762–88.
G. sp.—Birmingham, Hornerstown fm., ANSP 9554.
G. sp.—Vincentown, Hornerstown or Manasquan fm.?, ANSP 9366.
G. sp.—Burlington, Hornerstown fm., ANSP 9384.
G. sp.—Blackwood, Hornerstown fm., ANSP 9416–9.
G. sp.—N.J., ANSP 9369, 9231.

Order SAURISCHIA
Suborder THEROPODA
Family COELURIDAE
Genus DRYPTOSAURUS Marsh (1877, p. 88)

Dryptosaurus aquilunquis Cope—includes "*Laelaps*" Cope (1866, p. 276).
D. aquilunquis Cope—W. Jersey Marl Co., Sewell, Hornerstown fm., ANSP 9995.
D. aquilunquis Cope (1869-70, p. 100)—Barnsboro, N.J., Hornerstown fm. Type: lost.
D. macrops Cope (1868c, p. 417)—*Coelosaurus* in part—New Jersey. Type: lost.
D. antiquus Leidy (1865, p. 110)—Burlington Co., N.J., Diplotype: ANSP 9222.

THEROPODA (Incertae sedis—Lull & Wright, 1942)
Genus PNEUMATOARTHRUS Cope (1870c, p. 445)

Pneumatoarthrus peloreus Cope (1870c, p. 446)—Type: lost.
P. peloreus Cope—Monmouth Co., N.J., ANSP 9225.

Order ORNITHISCHIA
Suborder ORNITHOPODA Marsh
Family HADROSAURIDAE Cope
Genus ORNITHOTARSUS Cope (1869–70, p. 123)

Ornitholarsus immanis Cope (1869–70, p. 123)—Type: YPM 3221, 2½ mi. East of Keyport, N.J., Lorillard Company pit?, Woodbury fm.
O. immanis Cope—Merchantville, N.J., Merchantville fm., ANSP 8956.

Genus HADROSAURUS Leidy (1858, p. 215)

Hadrosaurus cavatus Cope (1871, p. 50)—New Jersey. Type: AMNH 1390.
H. foulkii Leidy (1858, p. 218)—Haddonfield, N.J., Woodbury fm. Type: ANSP 1005.
H. foulkii Leidy—Barnsboro, N. J., Hornerstown fm., ANSP 10007.
H. cf. *H. foulkii* Leidy—Barnsboro, N.J., Hornerstown fm., YPM 3216.
H. minor Marsh (1870b, p. 2)—Barnsboro, Hornerstown fm. Holotype: YPM 1600.
H. minor Marsh—Swedesboro, Marshalltown fm., YPM 1587.
H. minor Marsh—Mullica Hill, Hornerstown fm., YPM 1593.
H. minor Marsh—Sewell, N.J., Hornerstown fm., ANSP 15237.

Unidentified Dinosaurs

1. large reptile—Swedesboro, N.J., Marshalltown fm., ANSP no number.
2. Ayerstown, N.J., ANSP no number, Hornerstown fm.

Class AVES
Subclass NEORNITHES
Order PELECANIFORMES
Suborder PELECANI
Superfamily SULOIDEA
Family SULIDAE (Boobies and Gannets)
Genus MORIS Leach (1816, p. 35)

Moris loxostyla Cope (1870, p. 236)—New Jersey, Miocene. Type: *Sula loxostyla*, Calvert Cliffs, Md., Miocene.

Genus SULA Brisson (1760, p. 494)

Sula atlantica Schufeldt (1915, p. 62)—New Jersey, Miocene. Type: YPM 937.

Family PHALACROCORACIDAE (Cormorants)
Genus GRACULAVUS Marsh (1872a, p. 363)

Graculavus pumilus Marsh (1872a, p. 364)—Hornerstown, N.J., Hornerstown fm. YPM 850. Type: YPM 1209, Battle Creek, Kansas.

Genus LIMOSAVIS Lambrecht (1921, p. 55)

Limosavis velox Marsh (1872a, p. 364)—(*Graculavus*) Hornerstown, N.J., Hornerstown fm., Type: YPM 855.

Order GRUIFORMES
Suborder GRUES
Superfamily RALLOIDEA
Subfamily RALLINAE (Rails)
Genus TELMATORNIS Marsh (1870c, p. 210)

Telmatornis affinis Marsh (1870c, p. 211)—Hornerstown, N.J., Hornerstown fm. Type: YPM 845.
T. priscus Marsh (1870c, p. 210)—Hornerstown, N. J., Hornerstown fm. Type: YPM 840.
T. rex Shufeldt (1915, p. 27)—Hornerstown, N.J., Hornerstown fm. Cotypes: YPM 904, 948.

Order DIATRYMIFORMES (Diatrymas)
Family DIATRYMIDAE
Genus DIATRYMA Cope (1876, pl. 2, 5.)

Diatryma regens Marsh (1894, p. 344)—(*Barornis*), Squankum, N.J., Manasquan fm. Type: YPM 417.

Order CHARADRIFORMES (Plovers, Turnstones and Surf-birds)
Suborder CHARADRII
Superfamily CHARADRIOIDEA
Family SCOLOPACIDAE (Snipe, Woodcock and Sandpipers)
Subfamily PALEOTRINGINAE
Genus PALAEOTRINGA Marsh (1870c, p. 208)

Palaeotringa littoralis Marsh (1870c, p. 208)—Hornerstown, N.J., Hornerstown fm. Type: YPM 830.
P. vagans Marsh (1872a, p. 365)—Hornerstown, N.J., Hornerstown fm. Type: YPM 835.
P. vetus Marsh (1870c, p. 209)—Arneytown, N.J., Hornerstown fm. Type: ANSP 13361.
P. vetus Marsh—nr. Arneytown, N.J., Hornerstown fm., YPM 2808.

Incertae sedis
Genus LAORNIS Marsh (1870c, p. 206)

Laornis edvardsianus Marsh (1870c, p. 206)—nr. Birmingham, N.J., Hornerstown fm. Type: YPM 820.

AVES Unidentified

Aves, New Jersey, ANSP 12138.
Aves, an ulna, New Jersey, ANSP 12140.
Aves, an humerus, Fostertown, N.J., ANSP, no number, Hornerstown fm.
Aves, Shiloh, N.J., Miocene, YPM 941, 942.

Class MAMMALIA
Subclass THERIA
Infraclass EUTHERIA
Cohort UNGUICULATA
Order TILLODONTIA
Family TILLOTHERIIDAE
Genus ANCHIPPODUS Leidy (1868b, p. 232)

Anchippodus riparius Leidy (1868b, p. 232)—Shark River, N. J., Shark River fm. Type: missing.

Superorder MESAXONIA
Order PERRISSODACTYLA
Suborder CERATOMORPHA
Superfamily TAPIROIDEA
Family RHINOCEROTIDAE
Subfamily CAENOPINAE
Genus DICERATHERIUM Marsh (1875, p. 242)

Diceratherium matutinum Marsh (1870b, p. 2-3)—Farmingdale, N.J., Kirkwood fm. Type: YPM 11873.
D. cf. *D. cookii* Peterson (1906, p. 281)—Farmingdale, N.J., Kirkwood fm., specimen not located. Type: 1572 in Carnegie Museum from western U.S.

Superorder PARAXONIA
Order ARTIODACTYLA
Suborder SUIFORMES
Infraorder PALAEODONTA
Family ENTELODONTIDAE
Genus DAEODON Cope (1879, p. 77)

Daeodon leidyanus Marsh (1893, p. 409) (*Ammodon*)—Farmingdale, N.J. Kirkwood fm. Type: YPM 12041 and 12048.

Infraorder SUINA
Superfamily SUOIDEA
Family TAYASSUIDAE
Subfamily TAYASSUINAE
Genus HESPERHYS Douglass (1933)

Hesperhys antiquus Marsh (1893, p. 411) (*Perchoerus*)—Farmingdale, N.J., Kirkwood fm. Type: YPM 11867.

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PALEONTOLOGICAL NOTES

TAXONOMY AND THE FOOTPRINTS OF TETRAPODS

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ABSTRACT—The taxonomic treatment of vertebrate trackways within the limits of the Linnaean system of nomenclature is recommended with certain reservations, for example, only the clearest records should be named specifically, and the minimum for type designation should consist of *three* consecutive sets of footprints, thus establishing gait and body proportions as well as anatomical detail of the feet.

Studies of tetrapod trackways from Recent to Paleozoic age have made of the writer a firm believer in the taxonomic treatment of these records of the past within the confines of the Linnaean system of classification. At present, this point of view, which is the conventional one historically, is in need of support and defense.

Several years ago, Faul and Roberts (1951) proposed and employed a unique and artificial system of classification of tetrapod footprints because, as Faul (1951) expressed it, "a foot is only a small part af an animal's surface, and correlation of footprints with skeletal remains is rarely practical," and "a fossil trackway is a uniquely dynamic record of ancient life, but it is not an organism and probably should not be described as such." In Faul's system, each author assigns his personal series of capital letters or combinations thereof to each species he describes. The letter (or letters) is followed by numbers indicating whether the trackway is quadrupedal or bipedal and how many digits are impressed. It is difficult to imagine how this system can be satisfactorily definitive for any universal treatment of trackways of tetrapods, and, of course, there is no provision for the multitude of invertebrate trails. The initial letters of the system have no apparent meaning, and the great majority of tetrapods are quadrupedal and pentadactyl. Although Faul is sincerely attempting a practical solution to a difficult problem in paleontology, his system of classification, while useful in a preliminary and local study, would create more chaos than now exists when applied as a general practice.

In commenting on descriptions of fossil footprints by Colbert and Schaeffer (1947) and by Dunkle (1948), Faul (1951) states that these authors "raised strong objections to the prevalent custom [of employing the Linnaean system], on grounds that it violates the basic concepts of zoological nomenclature, and went on to describe their fossil footprints without referring to them by name." Dunkle (1948) wisely refrains from assigning a binomial to the indistinct, isolated, and somewhat problematical footprints from Mississippian strata, and states, "No attempt here is made to assign these prints to any of the scientific names available because of the above uncertainties of interpretation and because of the questionable advisability of such practice." Colbert and Schaeffer (1947) state, "The desirability or validity of employing a Linnaean nomenclature for the designation of fossilized impression, borings, etc., made by extinct organisms is a problem with many ramifications and is therefore far too complex to be discussed here." These authors go on to mention some of the problems involved in the study of fossil footprints made by vertebrates with generalized foot structure, and decide not to designate their incomplete trackway of an amphibian as a Linnaean species. Dunkle, Colbert and Schaeffer recognize the problems involved but present no strong indictment of the principle under discussion here. Their refusal to give formal Linnaean names to poorly recorded and poorly preserved trackways is commendable, as it is similarly commendable to avoid naming poorly preserved and fragmentary skeletal remains. However, it is the writer's view that a clearly recorded and well preserved trackway of a

tetrapod which clearly indicates a definitive morphologic type is worthy of formal recognition and treatment within the Linnaean system.

The great majority of fossil footprints by virtue of their method of origin are indistinct and generally lacking in clear anatomical detail. Such records certainly do not merit formal recognition even though their occurrence may constitute important geological data concerning subaerial or aquatic environments of deposition. Most of the spectacular trackways of vertebrates in the Coconino sandstone described mainly by Gilmore, and also those described by Faul and Roberts (1951), are excellent examples of highly interesting and geologically important fossils which on close analysis lack sufficient detail for morphological study. It is perhaps our deep-rooted fascination for tracks of all kinds, and especially for the "living" traces of extinct organisms, that has led to the unnecessary plethora of Linnaean names applied to such fossil records. More conservative use of Linnaean names for fossil trackways would go a long way toward meeting the criticism against that use of the Linnaean system.

It is certainly true that the Linnaean system has been abused by describers of footprints. However, the fault seems to lie not with the footprints but with us, the human interpreters, who do not sufficiently understand or determine the true anatomical characters involved or study the manner in which living tetrapods record trackways. The primary approach to the study and naming of vertebrate trackways (and this may apply to invertebrate trails, as well) should be anatomical and functional rather than the purely typological which treats each impression with or without clarity and with or without distortions as an entity in itself. The latter kind of treatment has contributed greatly to a general distrust of all footprints as useful fossils, and has tended to relegate them to curio departments and to exclude them from biological classification. Therefore, the attempt should be made to collect as many clearly recorded and consecutive footprints as possible, and to base the specific description on an anatomical type founded on a composite of all available footprints and including especially the pattern of successive footprints which all together constitute the trackway. This procedure, pioneered by German workers, for example, Soergel, produces as complete a reconstruction as possible of the original foot and body proportions of the animal which made the trackway. A minimum record for type designation should consist whenever possible of three consecutive sets of footprints so that right and left pes (and manus, if quadrupedal) *and* the trackway pattern are represented. One may easily imagine the futility of treating the simple mark of an invertebrate appendage as a type specimen—ignoring the trackway pattern. Yet this treatment often has been given, and often needlessly, to vertebrate trackways.

The feet of tetrapods have often been remarkably adapted to various modes of terrestrial locomotion; therefore, much anatomical detail may be reflected in their trackways. Two of the most distinctive extinct tetrapods were the reptilian originators of the Triassic trackways, *Chirotherium* and *Rotodactylus*. Numerous anatomical details are clearly recorded in their footprints, for example, attitude of the foot (primitive digitigrady), shape and size of claws, number of phalanges, arrangment and disposition of pads, and scale pattern. Details of the trackway pattern divulge further facts of taxonomic import, for example, a clear indication of a bipedal trend of the archosaur type. These trackways represent otherwise unknown species of pseudosuchians probably ancestral to archosaurs, and demonstrating two possible methods not demonstrated by any skeletal remains by which digitigrady evolved among archosaurs. Here is ample reason for taxonomic treatment within the Linnaean system. Furthermore these footprints constitute valuable guide fossils for the Triassic period. The footprints occur widely in Europe and in western and eastern United States. Recently *Chirotherium* has been identified in Argentina in strata formerly thought to be Upper Permian, and is thus important to our understanding of intercontinental correlations and intercontinental connections.

A clearly recorded, consecutive series of footprints, that is to say, a trackway, of a

tetrapod is as a rule generically distinctive relative to neozoological classifications. This is demonstrated by trackways of salamanders of the Pacific Coast of North America (Peabody, 1940). Of course, the trackways of some tetrapods are much more distinctive than others depending on specializations of structure and gait. It is true that generalized foot structure and body proportions are features common to a great many amphibians and reptiles responsible for fossil footprints. However, the geologic range of tetrapod genera is well enough known at present so that any scheme of classification, biological or otherwise, precludes the lumping of seemingly similar trackways from widely separated periods of geologic time. In any case, the shortcomings of many trackways need not negate the advisability of giving biologic status to a clearly recorded trackway of a distinctive tetrapod such as *Chirotherium barthi*. This trackway affords more diagnostic detail of the originator than any one of its individual bones. Such a record we cannot afford to ignore, much less cast out of our biological classification.

It may be argued that a Linnaean name applied to a tetrapod trackway is subject to duplication because the originator may have gone on to record other trackways thus introducing unwarranted confusion into the nomenclature. Actually there is only a negligible chance of finding more than one trackway made by the same individual, extinct or living. On a typical mudflat the period of optimum impressibility is no longer than an hour or two, and the vertebrate leaving a trackway is almost always transient. The well-travelled surface diagrammed from Triassic strata by Peabody (1948, fig. 21) is a typical example showing no duplication by the several individuals leaving clearly recorded trackways. Duplication of the trackways of one individual by recurrence in a vertical section of strata is also a negligible factor. However, careless collecting of isolated footprints from one horizon may lead to needless duplication. Trackway records need not present more and indeed should present less synonymy in nomenclature than such fossils as the successive moults of arthropods or the scattered fragments of one vertebrate skeleton.

A charge often levied against trackway records is that they are not organic, for they represent the trace of an organism that has moved elsewhere. While true, this objection is considerably neutralized by the unique, dynamic quality of trackways representing as they do a living, moving individual—not a dead and dismembered one. Also, were the organic content of a fossil the sole prerequisite for biological classification, few fossils would quality. The clear imprint of a tetrapod foot is as valid a testimony to the existence of an individual as is the trace of a dead fragment such as the impression or cast of a shell sometimes employed for specific description of fossil invertebrates.

Our general inability to correlate trackways with species based on skeletal remains is not a valid reason for exclusion of trackways from the biologic realm, or from the Linnaean system. This lack of correlation is caused mainly by the general incompleteness of the fossil record, and should not be construed as a condemnation of trackways as valuable biological records. Since trackways of tetrapods reflect the soft anatomy directly and the skeleton only indirectly, it is almost impossible to expect an absolute correlation with species based on skeletal remains. But in this inherent difference lies one of the most important contributions of the tetrapod trackway. It is a record primarily of a part of the soft anatomy otherwise unrecorded for the most part throughout tetrapod history.

The unique value of a tetrapod trackway is nowhere better demonstrated than by the trackway of a sauropod dinosaur recently installed in the American Museum of Natural History. This trackway is effective testimony that despite inconclusive deductions based on numerous skeletons, the giant sauropod did on occasion walk unsupported by water and recorded a typical subaerial trackway demonstrating the fact. Also demonstrated is the fact that the heavy tail dragged only lightly if at all on the ground. Neither of these functional characteristics may be surely ascertained from a study of the skeleton.

The practice of separating the Linnaean nomenclature of trackways from that of skeletal and other organic remains has been followed by taxonomists for many

years. A notable exception is the treatment of chirothere footprints in Von Zittel's catalogue. The writer's opinion is that the nomenclature of trackways should be maintained separately under the general heading, "Ichnites," as is done in the Camp et al., bibliographies of fossil vertebrates. However, the same methods and rules of Linnaean nomenclature should apply equally to trackways and to skeletal remains. Whenever possible generic names coined for trackways should indicate that a footprint record is involved, for example, the Permian amphibian trackway, *Hyloidichnus bifurcatus* Gilmore.

In summary: If we once admit that tetrapod trackways are bona fide indications of past life, then we should treat them accordingly, that is, within our standard biological classification. Such treatment does not mean that there are not many problems involved or that many inadequacies do not remain, but much can be done to give tetrapod trackways greater validity and usefulness within the confines of the Linnaean system. If one can demonstrate from a tetrapod trackway that it was made by a particular form of life having diagnostic physical and functional characteristics, then the use of a specific Linnaean binomial is justified. This procedure with trackways must presuppose, however, that great care be taken in collecting and describing, and that the morphological characteristics impressed in the trackway be distinguished from distortions and other inorganic characteristics originating from the type and consistency of the recording medium. All this cannot be done effectively without the insight provided by detailed study of the trackways of Recent tetrapods.

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HELICOPRION FROM ELKO COUNTY, NEVADA

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ABSTRACT—An example of *Helicoprion* from northeast Elko County, Nevada, was discovered in quartzites which underlie limestones with *?Schwagerina* sp. The specimen gives further evidence of the range of this selachian genus, indicating an occurrence in beds of Wolfcamp age or older.

During the summer of 1950 the junior author found an example of the selachian tooth structure *Helicoprion* while mapping in the vicinity of Contact, Elko County, Nevada. The specimen is the only fossil found in a conspicuous unit of reddish brown weathering quartzite which forms the east peak of China Mt. in the NW ¼ Sec. 22, T. 44 N., R. 64 E., about 6 miles southeast of Contact.

The Contact *Helicoprion* is an impression approximately 100 mm. in diameter consisting of about 1¾ whorls with 34 recognizable teeth in the inner whorl and about 27

in the preserved portion of the outer. A fairly well preserved denticle in the middle of the outer whorl is 25 mm. long, the blade being 8 mm. long and 6.5 mm. wide with an apical angle of 30°. The volution height is 20 mm. and the interdental space 2 mm. The narrowed base of each denticle orginates under the center of the previous one. The form of most teeth has been partly destroyed by weathering and the gross form of the whorl distorted by inter-stratal slippage.

Overall dimensions of the specimen and dimensions of the better preserved teeth above suggest *H. ferrieri* (Hay), but specific identification is not possible.

Partly silicified limestones which overlie the quartzite contain poorly preserved fusulines. M. L. Thompson, who kindly consented to examine these specimens, says: (letter, March 12, 1952) "... I would judge they are of Wolfcampian age and should be referred to the genus *Schwagerina.*" The fusulines were previously misidentified as *Parafusulina* and assigned to the Leonardian or lower Guadalupian (Larson & Scott, 1951). Schrader (1935, p. 8) had assigned these beds to the Upper Carboniferous on the basis of poorly preserved crinoid remains which were examined by Girty.

Helicoprion was first described from the Permian of Russia (Karpinski, 1899) and has been found at other localities in Eurasia and Australia. *Helicoprion ferrieri* was described from the Phosphoria formation of Idaho by Hay (1907, p. 22; 1909, p. 52) who referred it to the genus *Lissoprion.* Other *Helicoprion* specimens have since been collected from that formation. Wheeler (1939) described *H. nevadensis* from the Rochester trachyte of the Lovelock area, western Nevada, and *H. sierrensis* from a glacial boulder of welded tuff found in Mohawk valley in the northern Sierra Nevada, California.

The genotype of *Helicoprion* was collected from the Artinskian limestones of the Urals (Karpinski, 1899), a horizon which corresponds approximately to the lower Leonardian of North America. Other Russian examples are from the *Omphalotrochus* zone of the "Uralian" which Dunbar (1940, p. 258) assigns to the zone of *Triticites* and correlates with the Missourian or Virgilian of the Pennsylvanian.

Helicoprion ferrieri (Hay) from the Phosphoria of Idaho is apparently younger than the Russian examples, as the Phosphoria is classified as lower Guadalupian (Word) by most authors and would thus correspond to the Kazanian of the Urals. *Helicoprion*-bearing beds at Contact conformably underlie Wolfcampian strata and are considered to be of that age or older. They are tentatively correlated with the upper portion of the Oquirrh formation of Utah and the upper Wells formation, each of which contains a Wolfcampian fauna.

The strata with *H. nevadensis* and *H. sierrensis* were classified as Artinskian or possibly Uralian because of the presence of the genus in beds of that age in Russia. However, it is seen that the *Helicoprion* biozone occupies a broad time band and the genus should not be used for precise correlation until more specific information is available.

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OCCURRENCE OF THE BRACHIOPOD *ISOGRAMMA* IN THE BAIRD FORMATION OF CALIFORNIA[1]

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ABSTRACT—A unique specimen of *Isogramma* cf. *I. pachti* (Dittmar) is described from a Baird formation faunule from Shasta County, California. This is believed to be the first record of *Isogramma* in rocks of Mississippian age in North America.

INTRODUCTION

A faunule from the upper part of the Baird formation contains a unique specimen of the brachiopod genus *Isogramma*. This is believed to be the first recorded occurrence of *Isogramma* in the Mississippian of North America. The fossils were collected in 1951 by Jacques F. Robertson of the U. S. Geological Survey.

Associated with the specimen is a rich fauna of typical early Carboniferous forms, some comparable with Brazer limestone species and others with European Viséan faunas. The assemblage is largely molluscan, pelecypods predominating, with brachiopods composing about one-third of the collection. A few bryozoan specimens and one piece of colonial coral make up the rest of the fauna. A partial faunal list includes:

Lithostrotion aff. *L. pauciradiale* (McCoy)
Fenestella sp.
Polypora sp.
"*Thamniscus*" sp.
Rhabdomeson sp.
Orbiculoidea aff. *O. damanensis* Sokolskaya
Orthotetes sp.
Isogramma cf. *I. pachti* (Dittmar)
Chonetes sp.
Linoproductus? sp.
"*Cancrinella*" cf. "*C.*" *undata* (Defrance)
Dictyoclostus cf. *D. scabriculoides* Paeckelmann
"*Productus*" aff. "*P.*" *keokuk* Hall
Echinoconchus aff. *E. punctatus* (Martin)
Spirifer cf. *S. brazerianus* Girty
Spirifer sp.
Torynifer? sp.
Parallelodon aff. *P. reticulatus* (McCoy)
P. aff. *P. verneuilianus* (deKoninck)
P. aff. *P. cingulatus* (McCoy)
Schizodus sp.
Aviculopecten aff. *A. fimbriatus* (Phillips)
A. aff. *A. dissimilis* (Fleming)
Straparollus (*Straparollus*) sp.
Euconospira sp.
Mooreoceras? sp.

[1] Publication authorized by the Director, U. S. Geological Survey.

Similar faunas were collected years ago from the Baird formation along the McCloud River about three miles north of this locality. An extensive faunal list given by J. P. Smith (1894, pp. 549–597) indicates the same predominance of the molluscan element. Nearly all the forms listed above can be recognized in Smith's list, although the names and degree of certainty concerning identifications differ. In the collections of the U. S. Geological Survey, six localities in the same general area also produce faunas quite like the one under consideration. Although *Gigantoproductus* was not collected by Robertson, the genus was listed by Smith and is present at two, possibly three, of the localities mentioned above. I consider the absence of this large brachiopod here to be of no particular significance. *Gigantoproductus* is not commonly found in the molluscan facies. A consideration of the entire faunule points to a Viséan age compatible with the occurrence of *Gigantoproductus*.

The Baird fauna, like related ones from Alaska, shows a marked resemblance to Western European and Russian Lower Carboniferous faunas, as was pointed out by Smith long ago (1894, p. 598).

Miss Helen Duncan identified the corals and bryozoans, and she makes the following statement (personal communication, March 1955):

The coral from the limestone is *Lithostrotion* aff. *L. pauciradiale* (McCoy). It is certainly not a species that could be confused with any of the so-called Lithostrotions that Meek described from the McCloud limestone. Most, if not all, of those are probably lonsdaloids or possibly *Lithostrotionella*. Some of the McCloud species were originally listed as occurring in the Baird shale, but I believe that either the identifications were erroneous—many of the older identifications were made without benefit of sections and by paleontologists who knew essentially nothing about

corals—or that limestones of McCloud age were mistakenly included in the Baird. Some lithostrotionid corals in our reference collections from the Baird shale are very much like this particular specimen.

All the bryozoan genera identified range throughout the Carboniferous and Permian, but the general aspect is pre-Permian because several generic types that almost invariably occur in Permian bryozoan faunules in the west are absent. The specimens I am calling "*Thamniscus*" appear very much like a bryozoan I have collected in the Mississippian (probable Brazer equivalent) of north-central Nevada where it is also associated with *Rhabdomeson*. The occurrence of *Rhabdomeson* in the Mississippian of the west has not been reported previously.

Species of *Isogramma* have been reported from the Lower Carboniferous of Germany, Scotland, and Russia. In North America the genus has previously been found only in rocks of Pennsylvanian and Permian age.

SYSTEMATIC DESCRIPTION

ISOGRAMMA cf. I. PACHTI (Dittmar)

Text-fig. 1

Description.—Shell transversely elongate, width about twice the length; subelliptical; hinge line nearly straight; cardinal angles rounded; greatest width just anterior of the hinge margin; surface with fine, rounded, concentric lines about twice as wide as the interspaces; about 8 lines in 2 mm. near anterior margin, 14 to 16 lines in 2 mm. near beak.

Brachial valve nearly flat, gently concave in median part, slightly convex in posterior-lateral parts. Internally has rather short, low median septum extending 4–5 mm. anteriorly from base of stout cardinal process; details of cardinal process not shown; muscular impressions indistinct; shell apparently punctate. Pedicle valve unknown.

Measurements.—Width, 22.3 mm.; length, 11.2 mm.; hinge width, 21.6 mm.

Figured specimen.—USNM 119166; USGS locality number 14983.

Horizon and locality.—Baird formation, silicified phase of a limestone lens; approximately on boundary between sec. 3, T. 33 N., R. 4 W., and sec. 34, T. 34 N., R. 4 W., ½ mile SE of Pit Bridge on ridge crest; Shasta County, California.

Discussion.—This specimen approaches *I. pachti* (Dittmar) from the Lower Carboniferous of Russia in size and ornamentation, perhaps differing by being flatter, although this point cannot be proved definitely until a pedicle valve is found. From original figures of *I. pachti* (Dittmar, 1872), it can be seen that the ratio of shell width to length for the brachial value is somewhat less than that of the Baird form. Measure-

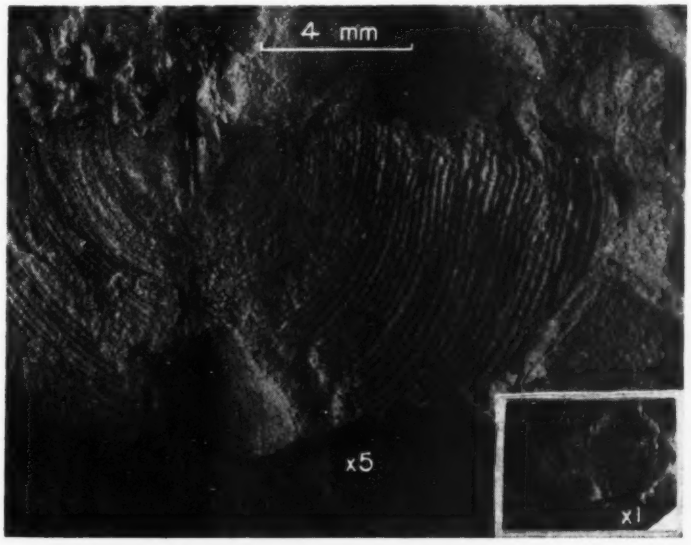

FIG. 1—*Isogramma* cf. *I. pachti* (Dittmar). From the Baird formation, Shasta County, California. Brachial interior. ×1 and ×5. USNM 119166.

ments of brachial valves show that the W/L ratio for *I. pachti* ranges from 0.4 to 0.5 whereas that of the Baird specimen is just over 0.5.

The two forms have similar ornamentation, both with about 8–10 lines in 2 mm. near the anterior margins of the shell. Specimens referred to *I. pachti* by Sarycheva & Sokolskaya (1952) appear much like the original material. No other Lower Carboniferous species is comparable. *I. germanica* Paeckelmann (1930) and *I. davidsoni* (Barrois), as illustrated by Davidson (1862, 1884), have much coarser concentric lines.

An interesting pathologic feature is the repaired area near the anterior margin. Either an injury or the adventitious inclusion of a foreign body resulted in abnormal shell growth. The otherwise regular concentric lines are interrupted and ring the irregular area much like contour lines on a hill.

The concentric lines, crowded in the umbonal region, are less closely spaced near the anterior and lateral margins. An abrupt change in spacing, about 5.5 mm. away from the beak, may reflect two very different rates of growth.

The relatively short median septum (compared to the shell length) appears to be characteristic of earlier species of this genus. *I. germanica* and *I. pachti* have short septa and short platforms in the pedicle valve. This is in contrast to the long septa and relatively large platforms in the Upper Carboniferous species: *I. millepunctata* Meek & Worthen, *I. renfrarum* Cooper, *I. texanum* Cooper, *I. paotechowensis* Grabau and Chao, and *I. ussensis* (Dittmar).

The genus has been fully discussed by Cooper (1952) and Aigner & Heritsch (1931).

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PALEONTOLOGISTS IN AMERICAN MEN OF SCIENCE

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The new edition of American Men of Science provides an opportunity for determining how American paleontologists consider their specialties to be related to geology and biology. Volume 1 of this new reference work is restricted to the physical sciences (including geology) and the inclusion or omission of names is instructive.

The accompanying table shows in column 1, the number of persons, members of the Paleontological Society in 1954, whose biographies are included in the 1939 edition of American Men of Science arranged according to classifications of their own choosing at that time. Column 2 shows how these same persons, whose biographies appear in volume 1 of the new edition, now classify themselves. Column 3 shows the number of persons in the original group whose biographies have been omitted but whose names appear with cross reference to volume 2 (not yet published) which will be devoted to the

MEMBERS OF THE PALEONTOLOGICAL SOCIETY WHOSE BIOGRAPHIES APPEAR IN AMERICAN MEN OF SCIENCE

		1939	1955, vol. 1		
			Biog.	Ref.	Omit.
Biology		2			2
Botany		4			4
Cartography			1		
Economic geology		2	2		
Geology		149	149	2	1
Economics		1	1		
Invertebrate paleontology	*	1	1		
Invertebrate paleozoology	*	1		1	
Micropaleontology	*	1	2		
Paleobotany	*	2	2		
Paleontology	*	25	28	1	2
Physiography		1	1		
Vertebrate paleontology	*	1		1	
Mammalology	*	1		1	
Ichthyology, Zoology		1			1
Invertebrate paleontology	*	5		3	
Paleoecology	*	1			1
Stratigraphy	*	1		1	
Malacology		1			1
Mammalology		1			1
Micropaleontology	*	3	2	1	
Natural Science		1			1
Ornithology		1			1
Paleobotany	*	7	1	3	1
Geology	*	1	1		
Paleontology	*	53	24	13	2
Biology	*	1		1	
Conchology	*	1		1	
Geology	*	6	7		
Paleoecology, Stratigraphy	*	1			
Stratigraphy	*	1	3		
Zoology	*	2	1	1	
Petroleum geology		2	6		
Physics		1	1		
Protozoology		1			1
Stratigraphic paleontology	*	1	1		
Stratigraphy			2		
Invertebrate paleontology	*		1		
Paleontology	*	2	2		
Structural geology		1			
Vertebrate paleontology	*	14		10	2
Zoology		4			4
Vertebrate paleontology, Anatomy	*	1			1
Totals		306	240	40	26
Totals, starred groups		133	76	38	9

biological sciences. They evidently wish to ally themselves with the biologists but recognize the relation of their specialties with geology. The last column shows the number of persons in the original group whose names are entirely missing from the new volume 1. A few of these are deceased but the others appear to recognize no relation to geology.

The 306 persons considered here constitute about 38 per cent of the total 1954 membership of the Paleontological Society. Doubtless a larger percentage will be included in volumes 1 and 2 of the new edition but the 306 include most of the prominent American paleontologists of today. Also included, however, are some persons who take an interest in, rather than contribute to, paleontology in any way.

The 66 "biologists" of columns 3 and 4

constitute about 21 per cent of the entire group. They include, however, persons whose classifications suggest very minor interest in paleontology. These serve to balance the non-contributors in the "geologic" group.

If the count is restricted to persons whose classifications indicate an active interest in some type of paleontology (starred groups) the proportion of "biologists" rises to about 36 per cent. This figure is too high, however, because a considerable number of persons classified under "geology" alone (nearly one-half of the 306) are prominent and productive paleontologists whose work is of as high a standard of excellence on any basis of comparison as is that of the average of the "biologists." A review of these persons indicates that about 27 per cent have predominantly paleontologic interests and about 44 per cent have predominantly non-paleontologic interests. If one third of this group be accepted as paleontologists, which does not seem to be unreasonable, about 28 per cent of active American paleontologists have chosen to align themselves with the biologists.

Vertebrate paleontologists and paleobotanists as groups are much less concerned with geology than are invertebrate paleontologists. If they are excluded from these calculations, there appear to be about 19 per cent of the invertebrate paleontologists who consider themselves biologists.

It might be reasonable to assume that recent discussion of the relations of paleontology to geology and biology (Knight, 1947; Weller, 1947; Newell & Colbert, 1948) has influenced a considerable proportion of younger paleontologists to profess predominant biological leanings but this does not appear to have occurred. An investigation of age groupings shows that the average age of "biologists" in the starred groups is only one year less and their median age only two years less than among the "geologists."

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ANNOUNCEMENT

ILLINOIS SURVEY TO OBSERVE FIFTIETH ANNIVERSARY ON OCTOBER 11

Friends and "alumni" of the Illinois State Geological Survey, delegates of national and local societies in geology and related fields, and delegates from universities and colleges will attend the Fiftieth Anniversary of the Survey on October 11, 1955, at Urbana-Champaign. An 8-page announcement and historical review has been issued by the State Board of Natural Resources and Conservation, copies of which may be had by writing the Illinois State Geological Survey, Urbana.

The Survey has had a steady development in both fundamental and applied research. Now its full-time staff exceeds 125, of whom some 75 are professional geologists, chemists, physicists, and mineral economists, and 50 comprise the supporting staff.

The Survey has its own quarters in the recently completed Natural Resources Building and accessory units, built and equipped by the State of Illinois for the sole use of the Geological and Natural History Surveys at a cost of about $3,500,000. The laboratories of the Geological Survey number 40.

Two themes will characterize the anniversary program: "The Survey's response to the changing economic pattern of the past fifty years," and "The relation of mineral resource research in Illinois to the economy of the State." During the forenoon of the following day the laboratories will be open for inspection, and during the afternoon the Illinois Survey will be host to the Association of American State Geologists.

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NOMENCLATURAL NOTES

PHALAGNOSTUS, NEW GENUS FOR TRILOBITE *BATTUS NUDUS* BEYRICH

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In 1822 Brongniart proposed the genus, *Agnostus*, with *Agnostus pisiformis* as the type species. In 1828 Dalman proposed to substitute the name, *Battus*, for *Agnostus*, again with *Agnostus pisiformis* Brongniart as the type species. *Battus* Dalman, 1828, thus became an objective junior synonym of *Agnostus* Brongniart, 1822. Nevertheless in 1845 Beyrich assigned to *Battus* a new trilobite from the Middle Cambrian of Bohemia which he called *Battus nudus*. This new species was so different from *Agnostus pisiformis* Brongniart that Beyrich's reference of it to *Battus* (=*Agnostus*) can not be accepted, although in 1852 Barrande placed it (*nudus*) in *Agnostus*, and he and many other authors have until recently continued to call it *Agnostus nudus* (Beyrich).

In 1847 Hawle & Corda proposed the genus, *Phalacroma* and assigned to it 12 species, among which were *Battus nudus* Beyrich [=*Agnostus nudus* (Beyrich) Barrande], *Phalacroma bibullatum* (Barrande), which had been described by Barrande in 1846 as *Battus bibullatus* and transferred by Barrande in 1852 to *Agnostus*, and a form, *Phalacroma scutiforme*, which Barrande, in 1852, rightly claimed to be identical with *Battus nudus* Beyrich. Hawle & Corda did not indicate a type species for *Phalacroma* in their text; but they figured only *Phalacroma scutiforme* [=*Battus nudus* (Beyrich)] as a typical example of *Phalacroma*.

In 1909 Jaekel proposed the genus, *Leiagnostus*, with the new species, *Leiagnostus erraticus* Jaekel, as the type species, and assigned *Battus nudus* Beyrich (which Jaekel referred to as *Agnostus nudus*) to the same genus (*Leiagnostus*). Beyrich's species, *nudus*, does not belong in *Leiagnostus*, however, and Jaekel's reference of it to that genus was an error.

In 1913 Raymond cited *Agnostus bibullatus* (Barrande) as the genotype of *Phalacroma* and assigned *Agnostus nudus* (Beyrich) also to that genus.

In 1935 Howell (1935a), believing that Hawle & Corda's figuring of *Phalacroma scutiforme* Hawle & Corda (*Battus nudus* Beyrich) as a typical example of *Phalacroma* constituted a citation of a type species for *Phalacroma*, and that Raymond's 1913 citation of *Agnostus bibullatus* (Barrande) as the type species of *Phalacroma* was therefore not justified, proposed the genus *Platagnostus*, with *Agnostus bibullatus* (Barrande) as the type species. In 1941 Richter claimed that Raymond's 1913 citation of *A. bibullatus* as the type species of *Phalacroma* was the first valid citation of a type species for this genus, and that *Platagnostus* Howell, 1935, was therefore an objective junior synonym of *Phalacroma* Hawle & Corda. Richter considered that *Battus nudus* Beyrich also belonged in *Phalacroma;* but *B. nudus* is so different from *P. bibullatus* that the two species can not be placed in the same genus.

In 1938 Harrington listed *Phalacroma* as a valid genus; and in 1939 Kobayashi discussed the genus at some length and also accepted it as a valid genus, with *Battus nudus* Beyrich as the type species, as Howell had done in 1935.

Westergård, in 1946, agreed with Richter's 1941 argument that Raymond's 1913 citation of *Agnostus bibullatus* (Barrande) as the type species of *Phalacroma* was valid, but noted that, if, as he believed should be done, *Agnostus bibullatus* (Barrande) was taken as the type species of *Phalacroma*, *Battus nudus* Beyrich should perhaps not be considered to belong in the genus *Phalacroma* because it differed from *Phalacroma bibullatus* in lacking any trace of axial furrows. Westergård, in this 1946 paper, also argued that *Grandagnostus*, a genus which Howell (1935b) had proposed in 1935, with

Grandagnostus vermontensis as the type species, should probably include *Battus nudus* Beyrich; but *Battus nudus*, as is shown below, differs so much from *Grandagnostus vermontensis* that the two species are probably not congeneric.

Thus, if Hawle & Corda did not properly cite *Battus nudus* Beyrich as the type species of *Phalacroma*, and if *B. nudus* does not belong in *Grandagnostus*, *B. nudus* has at this time no genus to which it can properly be referred, and it is necessary that a new genus be erected for it. The new genus, *Phalagnostus*, is therefore here proposed for it.

Phalagnostus is characterized by the subcircular form of its cephalon and pygidium, the wide border on its pygidium, and the elongate node on the axial portion of the pygidium. It may have a narrow border on the cephalon or may have no border on that shield. It lacks any traces of dorsal furrows on either the cephalon or the pygidium. The type species is *Battus nudus* Beyrich.

Phalagnostus differs from *Grandagnostus* in being smaller, in having a less quadrate pygidium, in having the node on the axial portions of the pygidium elongate, instead of circular, and in having a more circular cranidium. At least one species of *Grandagnostus*, *G. glandiforme* (Angelin), has a doublure on both the cephalon and the pygidium. No such doublure is known to be present on the shields of any species of *Phalagnostus*.

It is a debatable question whether Hawle & Corda's figuring of *Battus nudus* as a typical species of *Phalacroma* was a proper indication of a type species for that genus. The writer is inclined to believe that it was, but, since there is a difference of opinion on the matter, and since some of the editors of the Treatise on Invertebrate Paleontology do not consider that it was, it has seemed desirable to propose a new genus for *Battus nudus* at this time in order that the genus may be cited in the volume of the Treatise which will deal with the trilobites.

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SOCIETY RECORDS AND ACTIVITIES

The Pacific Coast Section of The Paleontological Society announces the election of the following slate of officers for the forthcoming year (1956):

Chairman: Harry E. Wheeler, Univ. Washington

Vice-chairman: Hans Thalmann, Stanford Univ.

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